From aid to responsible trade: driving competitive aquaculture sector development in Kenya

Quick scan of robustness, reliability and resilience of the aquaculture sector

B. Obwanga & M. R. Lewo

WAGENINGEN UNIVERSITY & RESEARCH

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B. Obwanga[1] & M. R. Lewo[2]

Edited by B. C. Bolman[3] and P.G.M. van der Heijden[4]

1. Egerton University, Kenya
2. State Department of Fisheries, Kenya
3. Wageningen Economic Research, The Netherlands
4. Wageningen Centre for Development Innovation, The Netherlands

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This report provides an overview of how the Kenyan aquaculture sector performs in three analytical domains: the robustness of the supply chain, the reliability of institutional governance and the resilience of the innovation system. Analysis is based on literature review, stakeholder interviews and a validation workshop guided by a SWOT framework to identify strengths, weaknesses, opportunities and threats. The findings inform on the existing opportunities and challenges that potentially influence growth in the aquaculture sector. The report is a first step towards documenting and sharing insights that support the move towards a more Robust, Reliable and Resilient (3R) aquaculture sector. The findings and recommendations presented may guide policy engagement and action in the transition of Dutch government bilateral engagement in Kenya from development aid–support to a trade-oriented approach, with a focus on partnership opportunities to drive competitive market-oriented aquaculture sector development that attracts private investments.

Keywords: Kenya, aquaculture, aid, trade, policy, development

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Contents

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Shortened forms

AAK	Aquacultural Association of Kenya
AFC	Agricultural Finance Corporation
ASDS	Agricultural Sector Development Strategy
ASDSP	Agricultural Sector Development Support Programme
BOMOSA	Consortium that includes BOKU, Austria; Moi University, Kenya; and Sagana Fish Farm, Kenya
DAD	Directorate of Aquaculture Development
DAR	Directorate of Aquaculture Research
DATD	Directorate of Aquaculture and Technology Development
DFID	Department for International Development
EKN	Embassy of the Kingdom of the Netherlands
EMCA	Environmental Management and Coordination Act
EPZA	Export Processing Zone Authority
ERS	Economic Recovery Strategy
ESP	Economic Stimulus Program
EU	European Union
FAO	Food and Agriculture Organization
FFEPP	Fish Farming Enterprise Productivity Program
GDP	Gross Domestic Product
GoK	Government of Kenya
KEBS	Kenya Bureau of Standards
KES	Kenya Shillings
KMAP	Kenya Market-led Aquaculture Programme
KMFRI	Kenya Marine and Fisheries Research Institute
LBDA	Lake Basin Development Authority
MOALF	Ministry of Agriculture, Livestock and Fisheries
MOFD	Ministry of Fisheries Development
NALEP	National Agriculture and Livestock Extension Programme
NAP	National Aquaculture Policy
NARDTC	National Aquaculture Research Development and Training Centre
NARSP	National Agricultural Research System Policy
NASDP	National Aquaculture Strategy and Development Plan
NASEP	National Agricultural Sector Extension Policy
NEMA	National Environment Management Authority
NGO	non-government organization
NOFP	National Oceans and Fisheries Policy
PD/A CRSP	Pond Dynamics / Aquaculture Collaborative Research Support Program
PPP	public–private partnerships
SDFBE	State Department for Fisheries and Blue Economy
SIDA	Swedish International Development Cooperation Agency
SMAP	Standard and Market Access Programme
SRA	Strategy for Revitalising Agriculture
SWOT	strengths, weaknesses, opportunities and threats
tonne	a tonne is a metric ton: 1000 kg
UNDP	United Nations Development Program
UNIDO	United Nations Industrial Development Organization
USD	United States Dollars
VAT	value added tax

Executive summary

The 3R (Robust, Reliable and Resilient) project assists the Embassy of the Kingdom of the Netherlands in Kenya in the transition from aid to trade. The project investigates whether the lessons from the development aid era can be transferred and scaled up in the upcoming transition to a trade era. The overall aim of the 3R Kenya project is to enable well-informed stakeholder actions that support the transition from development aid to sustainable trade (people, planet, profit) in the aquaculture, dairy and horticulture sectors. This quick scan focuses on the aquaculture sector.

The 3Rs have been defined as follows:

- Robust supply chain integration refers to efficient and trusted interactions between supply chain partners that reduce transaction costs and the risks involved in enhancing product quality and safety and reinforcing sustainability.
- Reliable institutional governance refers to public–private cooperation, co-innovation and a public economic policy framework that supports private investment and enhances opportunities for (inter)national trade.
- Resilient innovation systems (research, extension and projects) are those with dynamic adaptive capacities that enable agents and systems to adequately respond to changing circumstances.

This report covers the topic of freshwater aquaculture relating to the cultivation of fish in Kenya. The main species of study are the Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*). The production systems considered in the report are primarily extensive and semi-intensive pond cultivation. As the focus of 3R is on food and nutrition security, the authors have chosen to focus on domestic production and consumption.

Research questions

Based on the aim of the quick scan, three research questions were defined concerning aquaculture in Kenya:

1. What is the robustness of the supply chain?
2. What is the reliability of the institutional governance?
3. What is the resilience of the innovation system?

Methods and approach

To address the three research questions, a literature scan and stakeholder interviews were conducted. The strengths, weaknesses, opportunities and threats (SWOT) method was used to consistently collect and analyse data. Both peer reviewed and grey literature was searched for in Google Scholar and this was supplemented by literature in possession of the team members. The literature analysis was conducted using the Atlas.ti software. Based on relevant issues from the literature, stakeholders were identified, and further stakeholders were identified using snowball sampling. Interviews were conducted in a semi-structured manner.

Conclusions

For each of the three research questions, the most important findings are summarized below.

Concerning the robustness of the supply chain (i.e. its economic, social and environmental sustainability), most of the conclusions are related to economic sustainability:

1. Although not yet sufficient in size and quality, the most important elements of the aquaculture supply chain are in place. The elements include the various stages (pre-production, production, product handling, processing, marketing and consumption), actors and activities, with processing and value addition being especially underdeveloped. However, to make the sector, and investment in it, more profitable, the aquaculture sector has to move from its current level of small-scale production through to medium-scale and large-scale production.

2. There is a clear lack of robustness on the input side. This manifests in a lack of reliable, affordable and high quality feed and fingerlings (Rothuis et al. 2011, Rurangwa et al. 2015). Unscrupulous producers of feed and fingerlings have filled part of the supply gap with low-quality inputs. A lack of enforcement of quality standards made production and sale of inputs of compromised quality possible.
3. The limited growth in the number of entrepreneurs and the size of their enterprises limits the ability of the sector to scale up to a point where the supply chain is robust. While the number of entrepreneurs in the production side of the supply chain increased from 7,800 farmers in 2007 to an estimated 20,000 in 2011 (Rothuis et al. 2011), unfortunately the number of active farmers decreased after 2011 due to issues such as reduced availability of subsidised inputs.
4. There is high demand for fish and a dwindling supply from the capture fisheries. The supply chain is focused on two species, Nile tilapia and the African catfish, which are acceptable to consumers and are easy to culture. In areas with high consumer demand for fish there are opportunities for value addition in the supply chain through diversification; however, this is limited by the stagnation of the aquaculture sector at the small-scale level of production, so the opportunities remain unexploited. There are also no clear-cut markets for farmed fish, and the production of farmed fish is not consistent enough to maintain existing markets.
5. At the farm level, producers lack basic management, entrepreneurial and practical skills, such as general record keeping and estimating water quality on the basis of basic indicators such as temperature, oxygen levels and nutrient levels (Rurangwa et al. 2015, 2016). Such skills are needed to sustain aquaculture in the long term. The lack can be explained by a lack of (coordination in) education, training and extension efforts of supply chain stakeholders, the Government of Kenya (GoK), non-government organizations (NGOs) and donors.
6. Aquaculture production increased from approximately 4,000 tonnes in 2007 to approximately 20,000 tonnes in 2011, a growth of 400% (FAO 2014). This may be an overestimation, considering that a major part of this harvest came from ponds with low productivity that averaged 300 m^2 in size. The increase in production was aided by the increase in number of entrepreneurs, which was directly related to the Economic Stimulus Program (ESP) implemented by the GoK in the 2009/10 budget. However, despite the increased entrepreneurship and increased number of farmers and tonnage of fish harvested, businesses have not necessarily moved to a bigger and more efficient scale of production.
7. Cheap imports from China are a potential threat to the young sector. Detailed data and information on current and future fish imports from China (volumes, prices, trends and quality) are not available. Therefore, it is not yet clear to what extent these imports are affecting the aquaculture supply chain. It is also unclear if policy measures (e.g. duties and import tariffs) will be implemented to mitigate these effects and protect the infant sector.
8. The country is endowed with vast areas of aquaculture potential. The present low level of productivity makes the aquaculture supply chain environmentally sustainable. However, since production involves the use of water, there is a risk of environmental impacts on aquatic ecosystems once production increases. If the sector grows, the demand for high quality local feed will increase. This will increase the demand for feed ingredients, which causes pressures on resources such as land, water and on certain fish stocks used for fishmeal production. In addition, unmanaged and unplanned increase of production can also lead to conflicts with other water users. The spread of diseases and parasites can be a threat to the environmental sustainability of the supply chain and requires regulation and enforcement to reduce the risk.
9. A growing sector means a growth in demand for (local) feed. Feed production uses ingredients such as Omena (silver cyprinid, *Rastrineobola argentea*) and other edible products, causing competition for food, especially for poor households.
10. Low literacy levels, the influence of culture and religion and the barriers against participation of women and youth in the aquaculture sector are the critical issues affecting the social sustainability of the aquaculture supply chain. Although culture and traditions have a limiting influence on fish consumption in parts of the country, more youth are now consuming fish. However, the low uptake of aquaculture among women and especially youth is a thread for the social sustainability of aquaculture.

Regarding the reliability of institutional governance (i.e. how policies, standards and markets support private investment and enhance trade opportunities), it is concluded that:

11. Based on the problems facing aquaculture and the stagnation of the sector at a predominantly small-scale and extensive level of production since its introduction, we note that institutional governance is not yet reliable. The low priority that the sector has received from the GoK has caused lack of aquaculture-specific policies and regulations and little attention in GoK development programmes and strategies. Although there are numerous policies guiding aquaculture, they are fragmented and generic, making them weak and difficult to implement. While reasonable progress has been made on institutional strengthening of specific government bodies and developing aquaculture policy frameworks over the last seven years, two problems have impeded the implementation of these policy frameworks. The first is the changing of mandates among government institutes. The Directorate of Aquaculture and Technology Development (DATD), the Kenya Marine and Fisheries Research Institute (KMFRI) and the National Aquaculture Research Development and Training Centre (NARDTC) have overlapping responsibilities with respect to research, training and extension. Although these aspects are important to attract investment from the private sector, the urgency to streamline the integration of different departments for ease of operation has been low.
12. The second problem that impeded implementation (and limited the reliability of institutional governance) are the frequent transfer of the responsibility for aquaculture development from one government entity to another and aquaculture policies and regulations conflicting with those of other GoK sectors.
13. As long as aquaculture remains at a small-scale level, the availability of subsidy and credit systems (economic transfers) will be limited. Financial institutes regard aquaculture as a high-risk venture and hence are reluctant to give credit. The public–private partnerships (PPPs) and innovation platforms are still at the infancy stage, which means that there is opportunity to grow.
14. Regulations and standards for feed and fingerlings have been developed; however, enforcement and implementation of them is weak (Ngugi & Manyala 2009, Rothuis et al. 2011, Munguti et al. 2014a). Specifically, the problems of poor quality of fingerlings and feed point to a weak institutional framework and the inability of public and private stakeholders to improve these inputs. This is despite the fact that the Kenya Bureau of Standards (KEBS) is mandated to ensure the quality of inputs in the market. This lack of implementation of standards results in low levels of private investment and reduced trade opportunities.
15. There is lack of long-term funding and commitment to support the sector, from both national and international stakeholders such as governments, international organizations and NGOs. Moreover, efforts of funding organizations are not conducted in an integrated manner. Coordinated funding efforts are specifically required to improve the reliability of feed and fingerlings and to improve the entrepreneurial skills among actors in the supply chain where it has been found to be lacking, specifically among farmers. Cluster farming, PPPs and innovation platforms are possible forms of coordination that could be used to tackle this issue, but their potential is not (fully) utilized.
16. Subsidies under the Fish Farming Enterprise Productivity Program (FFEPP) boosted the sector between 2009 and 2011. However, the effectiveness of the subsidies was limited by failure to prioritise the large budgets allocated in areas with aquaculture potential (with favourable physical and ecological conditions). In addition, subsidies for fingerlings and feed were suddenly reduced, resulting in reduced fish production because smallholder fish farmers were reluctant or unable to purchase inputs (if available) at market prices.

Regarding the resilience of the innovation system (i.e. how stakeholders and systems support the creation of enabling conditions or remove barriers to innovation), it is concluded that:

17. Cooperation between stakeholders in the aquaculture supply chain is still far from optimal due to a lack of coordination of efforts and investments (Rothuis et al. 2011).
18. Most innovation support comes from various national and international government and non-government organizations. However, their approaches have not focused on enhancing long-term profitability in the supply chain. Furthermore, these organizations have not been able to adequately integrate technical and institutional innovations. The reasons for this lack of integration are unclear. While the GoK is investing in research infrastructure, the collaboration and cohesion between researchers, the private sector and producer organizations necessary for co-innovation is

limited. This may be related to the fact that there is no overarching innovation and/or stakeholder platform to facilitate collaboration and cohesion.

19. The extension system is further limited by low staffing and low financing. Training of graduates does not meet the requirements of the industry, and research is not responsive to the supply chain.
20. Inadequate and inconsistent socioeconomic, environmental and production data about the sector is a challenge. This can be explained by limited capacity for professional data collection by organizations such as the Kenya National Bureau of Statistics. Sound data are necessary to make informed decisions and are thus essential for the further growth and transformation of the sector.

Recommendations

The recommendations for more robustness in the aquaculture supply chain are :

a. To identify a working business model for Kenyan aquaculture that will move the sector from its current state to medium- and large-scale commercial farming where all elements of the supply chain are robust (conclusions 1, 2, 3 and 6)
b. To strengthen the implementation and enforcement of standards for local fish feed and fingerling production. KEBS urgently needs more capacity to do this (conclusions 2, 14 and 20).
c. To support and promote cluster faming among farmers in the supply chain. This will create increased bargaining power when they purchase inputs and invest in cold storage, processing and marketing (conclusion 4).
d. To improve the skills and practical knowledge of farmers in aquaculture, with special help given to women and youth, to form groups so they can take up fish farming. In such groups, the practical knowledge and skills of farming and marketing can be taught. This can be done by increasing the funding of training and extension programmes (conclusions 3, 5, 10, 15 and 19).

The recommendations for more reliability in institutional governance are :

e. To update the NAP and NASDP to make them more specific and make the objectives more realistic (all conclusions, but specifically 8, 12, 13 and 14)
f. To provide strategic guidance to the sector in the long term and plan for the right investment, taking guidelines to address environmental and social impacts such as provided by FAO for responsible aquaculture development, zoning and area management into consideration (conclusions 1, 8, 12, 14, 15 and 16)
g. To use soft instruments such as cluster farming, PPPs and innovation platforms to increase the reliability of institutional governance in the near future (conclusions 14, 15, 16, 17 and 18).
h. Informed decision-making on programmes, projects and investments can only occur with consistent and reliable facts and figures. There is urgent need to support the supply chain stakeholders, GoK entities and donors with such data. Improve the capacity-building for the Kenya National Bureau of Statistics so it can professionally collect sound data on aquaculture performance

The recommendations for more resilience of the innovation support system are :

i. To review training and extension programs for farmers, and to improve capacity-building of extension officers (conclusions 3, 4, 5, 9, 14 and 18).
j. To increase coordination among innovation system supporters by installing the proposed Aquaculture Advisory and Research Board or another multi-stakeholder innovation platform with similar function, and via (digital) innovation platforms to steer knowledge creation to solve problems with feed, fingerlings and other issues in the aquaculture chain. (conclusion 15, 17 and 18).

1 Introduction

Background

As part of the transition strategy from aid to trade, the Embassy of the Kingdom of the Netherlands (EKN) has commissioned the 3R (robust, reliable and resilient) Kenya project to assess the extent to which lessons can be learned from the EKN agriculture and food and nutrition security programmes, focusing on the horticulture, dairy and aquaculture sectors. The project investigates whether these lessons can be transferred and scaled up and, as such, be better anchored within the Kenyan agricultural sector (Rijn et al. 2016).

This report is the first part of a sector appraisal study on aquaculture in Kenya and is the result of a quick scan of the Kenyan aquaculture sector. This quick scan will be used to provide insight into the main issues with respect to the supply chain, institutional governance and innovation support system of freshwater aquaculture of the Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) in Kenya. It includes an overview of strengths, weaknesses, opportunities and threats (SWOT) in relation to the robustness, reliability and resilience of aquaculture in Kenya. The insights about the main issues from the quick scan provide input for the second phase of the sector appraisal, during which one or more specific issues of the quick scan will be selected for a more quantitative analysis to understand the essence of each issue and what can be done to tackle it.

Research objectives

The aim of the quick scan is to identify how the aquaculture sector in Kenya performs in terms of the robustness of the supply chain, the reliability of the institutional governance and the resilience of the innovation system.

These concepts are defined as follows (Wageningen UR 2015):

- The **robustness** of a supply chain refers to efficient and trustful interactions between supply chain partners that reduce transaction costs and risk for enhancing product quality and safety and reinforcing sustainability. This report highlights the robustness of the aquaculture sector in terms of economic, social and environmental sustainability.
- The **reliability** of institutional governance refers to public–private cooperation, co-innovation and a public economic policy framework that supports private investment and enhances opportunities for (inter)national trade. This quick scan focuses on how policies, standards and markets are supportive from a trade perspective, that is, the degree to which they support private investment and enhance trade opportunities.
- The **resilience** of the innovation system (which is composed of research, extension and projects) refers to dynamic adaptive capacities that enable stakeholders and system components to adequately respond to changing circumstances. In this quick scan, we focus on how the stakeholders and the innovation system components support technical, institutional and social innovations (the enabling conditions) or remove barriers that prevent these innovations from happening.

Research questions

Based on the aim of the quick scan three research questions were elaborated, all relating to aquaculture in Kenya:

1. What is the robustness of the supply chain?
2. What is the reliability of the institutional governance?
3. What is the resilience of the innovation system?

Research limitations

This report covers the topic of freshwater aquaculture, focusing on the cultivation of fish. The main species of study are tilapia and catfish. The production systems considered in the report are primarily extensive and semi-intensive pond cultivation. We consider the aquaculture supply chain as one supply chain connecting to other chains, so chains such as the feed and fingerling chains are integrated into this analysis. As the focus of 3R is on food and nutrition security, we have chosen to focus primarily on domestic production and consumption.

Structure of the report

This report is structured as follows. In Chapter 2, the approach and data-collection methods of the study are elaborated. In Chapter 3, an overview of the aquaculture sector in Kenya is presented. Chapters 4, 5 and 6 go into more detail with respect to robustness, reliability and resilience in Kenyan aquaculture through the SWOT lenses. Finally, Chapter 7 presents the conclusions of the quick scan and provides several recommendations.

2 Methods and approach

To answer the research questions, the following methods were applied:

Literature review

During an expert meeting in Nairobi in February 2016, key documents were selected that were considered a good starting point for a scan of the sector. They were coded in Atlas.ti, a software program that facilitates analysis of qualitative data. To supplement the information from these documents, additional grey information was obtained from team members and by searching the internet with Google using the snowballing method. To elucidate issues that came up during analysis, scientific literature was sought on a case-by-case basis using Google Scholar.

Interviews

Key stakeholders – be it individuals or organizations – in the Kenyan aquaculture sector were selected using the 3R aquaculture team's knowledge of the sector. This was done in such a way as to ensure inclusion of stakeholders of each step of the supply chain and from commercial companies, government and research and extension institutes. Key stakeholders were identified based on information from various sources, while additional stakeholders were identified during the fieldwork (snowball sampling). Annex 1 lists the stakeholders who were interviewed in May–June 2016. Information used in the report from these interviews is sourced with the name of the interviewee. Interviews were semi-structured, using open questions (Annex 2).

Validation and prioritization workshop

The findings from the literature review and interviews were written up in a draft report. The executive summary and a PowerPoint presentation summary of that draft were used as input for a stakeholder workshop held on 19–20 July 2016 in Nairobi (Annex 3). Invited stakeholders included those who were interviewed, supplemented with other key stakeholders, again based on team knowledge of sector stakeholders. The objectives of the workshop were to share the findings from the sector quick scan, obtain feedback from the stakeholders and to stimulate a sharing of their experiences. Feedback from this workshop was used to complement the draft report to produce this final report.

3 Characterization of the sector

This chapter characterizes the development of the aquaculture sector in Kenya. Despite Kenyan aquaculture being in its infancy and in dire need of development so it can reach maturity, it has potential to become a significant source of food (particularly of affordable, high quality protein), to reduce poverty and provide employment and to contribute to gross domestic product (GDP). Although data specific to aquaculture are not available, when aquaculture is combined with capture fisheries the two contribute approximately 0.54% of the country's GDP (Obiero et al. 2014, Ngwili et al. 2015, FAO 2016a). As an economic activity, aquaculture offers employment and a source of income for stakeholders in the supply chain in multiple rural communities. Although it is not clear how many jobs are currently available in the full supply chain, it was reported that the sector employed 67,883 fish farmers in 2013 (MOALF 2013a). However, despite the country being endowed with regions that have favourable climatic and geographic conditions for aquaculture investment (Rothuis et al. 2011, MOALF 2013a, Munguti et al. 2014a), aquaculture's contribution to total fish production in Kenya is low: just 14% in 2013. The production potential is strongest where farming conditions are favourable, and weakest in the arid and semi-arid areas (Musyoka & Mutia 2016) and where the population consists of traditionally non-fish-eating communities.

In Kenya, most fish farming is done in the freshwater environment, and mariculture is relatively undeveloped. Mariculture activities are limited to small-scale and community-based activities with no commercial farmers, despite the Kenyan shore along the Indian Ocean being approximately 640 km, with an abundance of unpolluted seawater (Rothuis et al. 2011). Within Africa, Kenya ranks fifth in total freshwater aquaculture production, with a total of 23,855 tonnes, after Egypt (932,450 tonnes), Nigeria (313,231 tonnes), Uganda[1] (111,023 tonnes) and Ghana (38,535 tonnes). Looking at both marine and freshwater aquaculture in Africa, Kenya ranks sixth (Figure 1). Among the sub-Saharan countries, Kenya is the third largest producer of Nile tilapia (18,072 tonnes), after Uganda (53,093 tonnes) and Ghana (36,900 tonnes) (FAO 2014a). This production earned fish farmers 5.5 billion Kenyan Shillings[2] (KES), which was a 19.6% improvement from the previous year, when farmers earned KES 4.6 billion (MOALF 2013a). Kenya has 1.4 million ha of potential aquaculture production area; only 0.014% is utilized, with 95% of the production being under small-scale aquaculture (Otieno, 2011 cited in Munguti et al., 2014a). The questions of where and to what extent it is advisable to develop and fully utilise this area remain to be answered. This estimate of potential production area does not take direct and indirect socioeconomic and environmental impacts into account.

[1] FAO and Government statistics may be different from the real production; in case of Uganda, real production is thought to be significantly lower (Rothuis et al. 2011).

[2] 1 USD = 101.81 KES as at 23 November 2016.

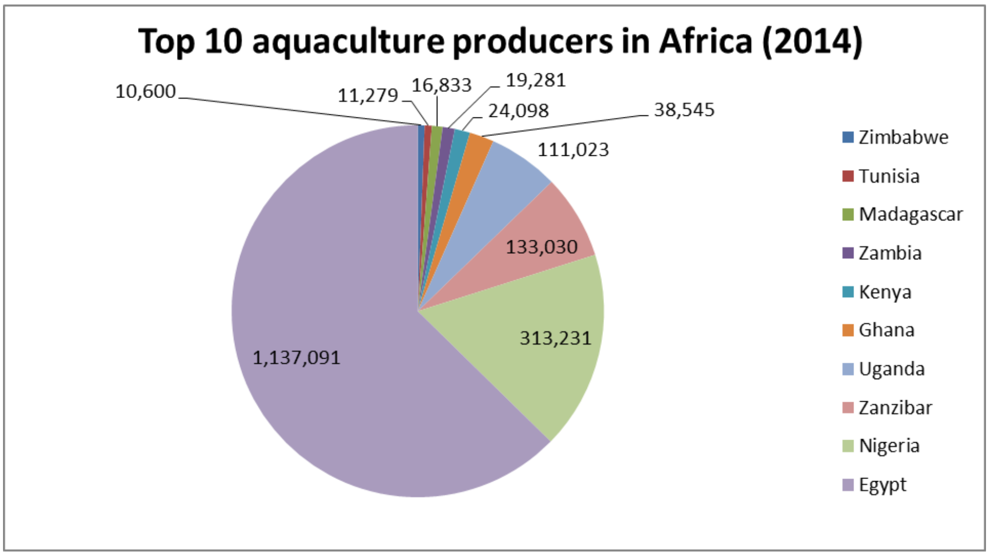

Figure 1 *Top 10 marine and freshwater aquaculture producers in Africa*
Source: FAO (2014a)

Development of aquaculture in Kenya replicates the scenario seen in the rest of sub-Saharan Africa, where it has been sporadic and in many cases has failed to live up to expectations since its introduction by the colonial governments. This is despite the numerous interventions by international development agencies and bilateral donor programs, together with the Government of Kenya (GoK) adopting aquaculture as a tool to reduce poverty between 1970 and 1995 (Ngugi & Manyala 2009, Heijden & Spliethoff 2014). The existence of approximately 28,000 fishponds ranging from 0.04 ha to 0.8 ha was reported in the 1960s, but most of them were abandoned due to lack of inputs (mainly feeds and quality seed) and perpetual poor harvests (Ngugi & Manyala 2009). Haight et al. reported the existence of 10,000 ponds in 1989, with only 5,000 being managed (Haight et al. 1990, cited in Ngugi & Manyala 2009). In an attempt to revitalise the growth of aquaculture in the country, the GoK through the Economic Stimulus Package (ESP) launched the Fish Farming Enterprise Productivity Program (FFEPP) in 2009, with an initial budget of KES 22 billion (Musyoka & Mutia 2016). The GoK identified small-scale fish farming as one of the economic pillars of the ESP to jump-start the economy, because despite the efforts of the GoK, fish farmers had abandoned fish farming (Kimathi et al. 2013). The program ran into 2013 with an additional KES 12 billion (GoK 2013). In its first phase (2009/2010 financial year), 140 political constituencies were selected to benefit from subsidies that included construction of 200 ponds (size 0.03 ha, or 300 m^2) and provision of 15 kg of fertilizer and 1,000 fingerlings of monosex (all male) tilapia in addition to catfish fingerlings (to check the population of tilapia) per fish pond. In the 2011/2012 financial year, 20 additional political constituencies were added and the number of ponds per constituency was raised to 300. Hence the two phases resulted in 48,000 ponds, each expected to produce 270 kg of fish per year (Musyoka & Mutia 2016). This explains the marked increase in aquaculture production after 2009 (Figure 2).

The FFEPP triggered a rapid growth in the sector (Rothuis et al. 2011, FAO 2016), with GoK support being provided in the form of subsidies for fingerlings, feed and pond construction. GoK embarked on aggressive “eat more fish” campaigns to create markets for the products (Munguti et al. 2014a). It is reported that through this programme, the aquaculture sector production increased from 2,000 tonnes/year in 2003 to 12,000 tonnes/year in 2013 (Musyoka & Mutia 2016). Despite the expectation that the implementation of the FFEPP in most parts of the country would translate into positive economic returns, its performance was below expectations due to a myriad of challenges. In some cases, fish ponds were abandoned even before fish were harvested due to management challenges. Many ponds were constructed in areas with unfavourable physical and ecological conditions, with temperatures too low for tilapia to grow well, with insufficient water and in areas with porous soils. In these areas, farmers were often not able to line the ponds to prevent water seepage. In some cases, farmers were still committed to the fish farming venture; however, they were yet to realize returns, due to the various challenges faced (Musyoka & Mutia 2016). The growth of aquaculture in Kenya remains limited by four main issues: lack of affordable high quality fingerlings and feeds, lack of entrepreneurial skills at the farm level and tilapia imports from China.

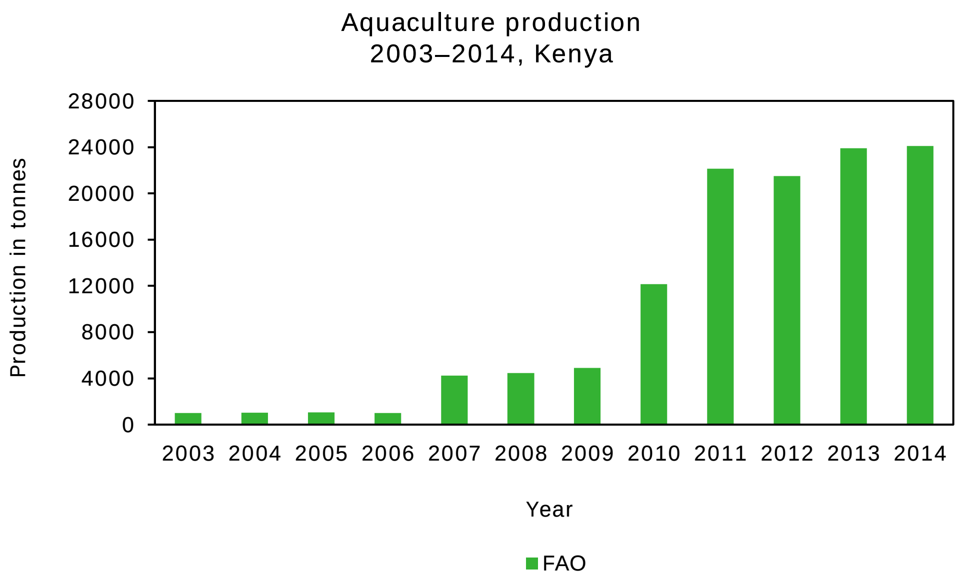

Figure 2 *Aquaculture production in Kenya between 2003 and 2014*
Source: FAO (2014b)

Kenyan aquaculture follows the style observed in a large area of sub-Saharan Africa, where fish farming is mostly done in earthen ponds ranging from 0.02–0.05 ha (200–500 m^2), which are fertilized with organic manure and where the fish are fed on locally available, low-cost agricultural by-products. Production in earthen ponds is popular with smallholders because this type of cultivation requires minimal input (start-up capital, fingerlings, feed, technology and general management practices) (Munguti et al. 2014a). This is supported by data from the Fisheries Department, which reports 69,194 earthen ponds (2,076 ha by the end of 2013, but only 161 tanks (2.31 ha) and 124 reservoirs (74.7 ha), with fishponds being mainly owned and managed by individual fish farmers, and self-supporting groups managing dams/reservoirs (MOALF 2013a). Aquaculture production in Kenya can be characterized as being extensive (productivity 500 – 1500 kg/ha/year) to semi-intensive (productivity approx. 3 tonnes /ha/year). More than 70% of the Kenyan farmed fish production is realised in semi-intensive production systems (Ngugi & Manyala 2009). Intensive farming through methods such as recirculation aquaculture systems or cages is seldom started, because the management, technology and infrastructure required are expensive (Munguti et al. 2014a). Due to inconsistencies in the reporting of data on farmed fish production and the number of production units (ponds, tanks or reservoirs), data on production are unreliable, leading to past trends in production being irregular (Ngugi & Manyala 2009).

The Nile tilapia (*Oreochromis niloticus*) and the African catfish (*Clarias gariepinus*) form the bulk of the species grown in the country (Figure 3). These two species are preferred because there is high demand for them in the market, they are tolerant to high stocking densities, they have resistance to diseases and they readily accept supplemental and manufactured feed (Ngugi et al. 2007).

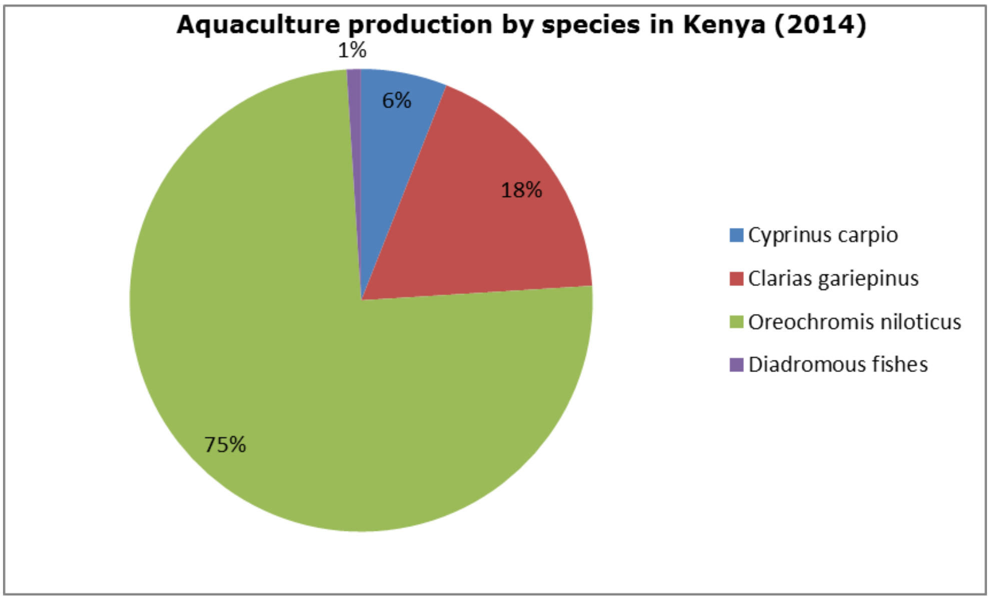

Figure 3 *Aquaculture production by species in Kenya in 2014*
Source: FAO (2016a)

Annual per capita fish consumption in Kenya is 5 kg, which is far below the 16 kg per capita consumed globally. Rothuis et al. (2011) calculated that just to maintain the 5 kg per capita consumption level (and assuming fish imports equalled production from capture fisheries and average productivity is 4 tonnes/ha), a production of 20,946 tonnes from 174,552 ponds (5,237 ha) would be required by 2015; 50,164 tonnes/year from 418,033 ponds (12,541 ha) by 2020 and 110,000 tonnes from 916,667 ponds (27,500 ha) by 2030. This production is to be realised in 0.03 ha (300 m^2) semi-intensive tilapia ponds. Alternatively, this production could also be achieved through intensive production of catfish from 279 farms (6 ha) by 2015, or 669 farms (13 ha) by 2020 and 1,467 farms (29 ha) in 2030. According to Obiero et al. (2014), the Kenyan population of over 40 million people requires over 500,000 tonnes of fish annually for domestic consumption, which can be met by further developing the aquaculture sector.

After the inception of the FFEPP in the 2009/2010 financial year, it was reported that the total area under fish ponds increased from 220 ha in 2008 to 468 ha in 2009, while the gross total land under aquaculture was 825 ha compared to 728 ha in the previous year. Fish production under the 825 ha of land was 4,890 tonnes in 2009 (FAO 2016b). This translated to an average production of 5 tonnes/ha/yr. Although the area under farming is not indicated, production in 2013 was reported to have increased to 23,501 tonnes, more than four times the production in 2009. A slight increase to 24,093 tonnes was reported in 2014 (FAO 2016c). Despite the lack of data for Kenyan aquaculture production in 2015, it is highly unlikely that productivity of even 4 tonnes/ha/yr was realised, because of reports of farmers abandoning fish farming due to the high cost of inputs, lack of technical expertise and water scarcity, among other challenges (FAO 2016b, Musyoka & Mutia 2016). To bridge the gap between local supply and demand, Kenya imports a substantial amount of fish. In 2013, for example, Kenya imported 5,269 tonnes (KES 524 million) of fish from mainly Asian countries such as India, Pakistan, Japan and Korea. The bulk of the imported tilapia (739 tonnes) originated from China; this accounted for 14% of the total fish and fisheries products imports (MOALF 2013a).

The different stakeholders in the aquaculture supply chain are shown in Figure 4. Fish farms are at the centre of the figure. The GoK plays an important overall role in supporting the development of the aquaculture sector, through development and implementation of policies and regulations.

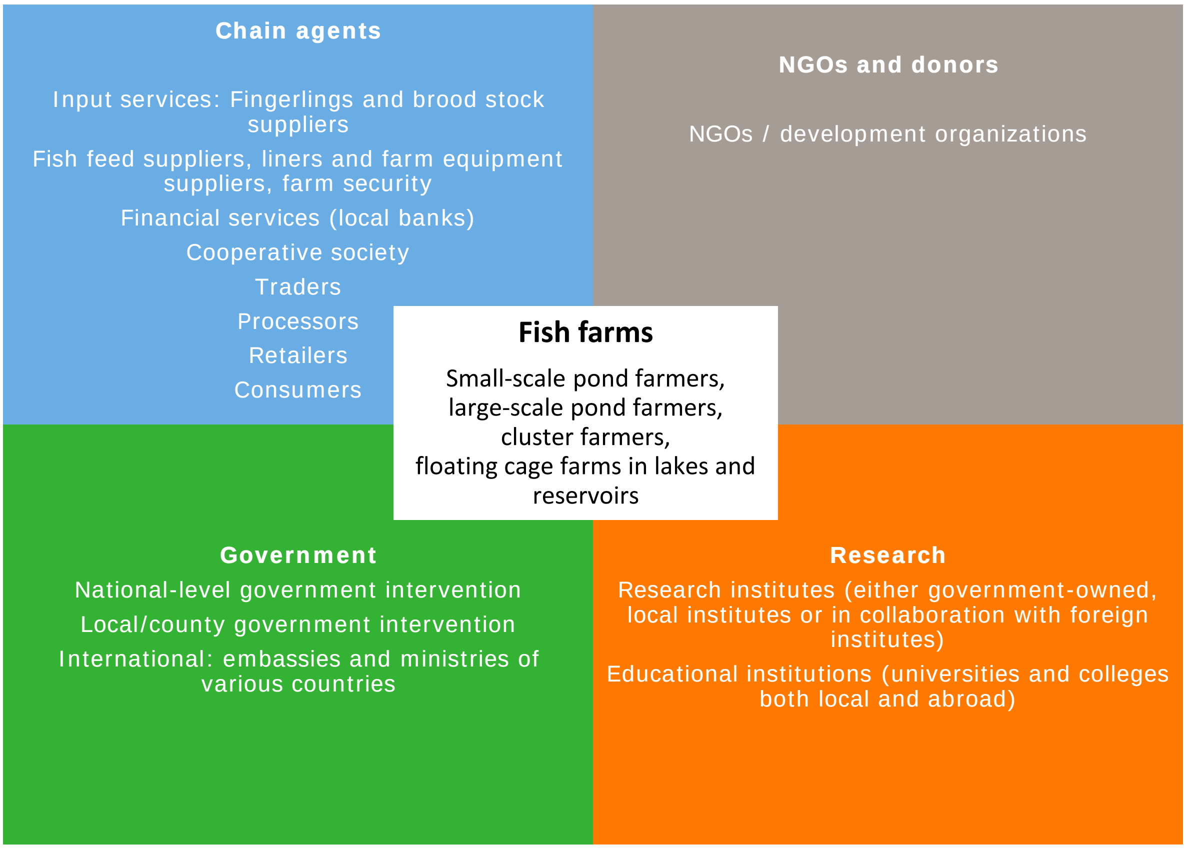

Figure 4 *Actors in the aquaculture supply chain*

Several GoK institutes and agencies are responsible for aquaculture development through policy development and implementation, training, research and extension (see full list in Annex 4). These institutes have been working either independently or in collaboration with other state departments. The GoK supports demand-driven, applied and participatory research and ensures that farmers have access – at least on paper – to GoK research facilities and scientists. However, despite there being both research and extension facilities in areas with aquaculture potential, the meagre funding to support facilities and staffing has limited their effectiveness in service delivery. This is further explained in Chapter 6. The GoK also collaborates with NGOs to set the research agenda, fund the research and evaluate and disseminate the results. The NGOs have been involved in training of farmers, extension and research officers on different aspects of aquaculture, including accessing markets, entrepreneurial skills and value addition, and development of simple, adaptable technologies, specifically at the rural level (Ngugi & Manyala 2009).

There has been a lot of support given to the aquaculture sector from the GoK, NGOs and bilateral and multilateral donor projects since it was introduced in Kenya before independence. The focus of these efforts was mainly at the inputs and production side of the supply chain.

Support has evolved from an emphasis on popularizing fish farming among rural small-scale farmers, propagating catfish and producing tilapia fingerlings to capacity-building for farmers and extension workers and establishing semi-intensive and intensive fish farming. However, continuity is the biggest challenge associated with bilateral- and multilateral-funded projects, which have been characterised by handouts, subsidies and so on, perpetuating overdependence of the farmers on free or subsided inputs and services. This has hampered farmers from becoming independent in the long term. This is an important explanation for the stagnation in the growth of the sector. The lack of continuity has also led to the current paradigm shift where most externally funded programmes have shifted from a single stakeholder perspective of donor-driven funding, which was common between 1960 and 2000, to multi-stakeholder-driven funding since 2000. Embedding the programmes in GoK activities has helped make the projects and programmes more sustained (Ngugi & Manyala 2009). Ngugi and Manyala (2009) report support to the tune of USD 13.25 million between 1970 and 1990 from 10 donors: the

World Bank, the European Union (EU), the United Nations Development Program, the International Development Research Centre, USAID, the Norwegian Agency for Development Cooperation, the International Foundation for Science, and the Belgian, Japanese and Italian governments. From 2000 onwards, other bilateral and multilateral donor agencies that have been active in aquaculture development include the Japan International Cooperation Agency, the British Department for International Development (DFID) and the Swedish International Development Cooperation Agency (SIDA). Also, there have been direct investments from countries such as Australia (USD 198.4 million), Israel (USD 49.6 million), the United Kingdom (USD 9.2 million) and India (USD 5.4 million) as reported in 2010 (Rasowo et al. 2008, Rothuis et al. 2011).

EKN is playing a great role in supporting commercialization of the sector. Currently EKN supports aquaculture in the western parts of the country through the Kenya Market-led Aquaculture Programme (KMAP) at a cost of EUR 4 million. This programme, which runs from 2016 to 2019, is implemented by Farm Africa in partnership with institutes under GoK and consultants and companies from the Netherlands and aims at empowering fish farmers to become more profitable. It builds on the success of the aqua shops concept that has been successfully implemented by Farm Africa in some counties in the western part of Kenya. It builds on a franchise model to establish a commercially viable input and service distribution system consisting of shops owned by local entrepreneurs that provide inputs and technical advice on best aquaculture practices. In this way, farmers are linked to markets that provide extra income (Farm Africa 2016).

Another example is FoodTechAfrica. This is a PPP initiative combining the strengths of Dutch agrifood companies (mainly SMEs), knowledge institutes, government agencies (such as EKN) and their East African counterparts to improve food security in East Africa through the establishment of a fully integrated aquaculture supply chain (Larive 2015).

As a step towards the analysis of issues in the robustness of the supply chain, the reliability of institutional governance and the resilience of innovation support systems in the following chapters, it can be stated that the aquaculture sector in Kenya has lagged compared to the dairy and horticulture sectors. Lack of or weak institutional and legal frameworks have contributed to the uncoordinated promotion of fish farming through many institutes in the GoK, research institutes, universities, NGOs, and bilateral and multilateral donor agencies (Ngugi & Manyala 2009, Shitote et al. 2013). Additionally, a lack of capacity to implement policies and aquaculture development strategies, as well as lack of legal enforcement, has caused the sector to suffer from issues of quality of feed and fish fingerlings. This has, in turn, limited production and hence stifled aquaculture growth (Ngugi & Manyala 2009, Shitote et al. 2013, Munguti et al. 2014a). It has been challenging for farmers to access established markets such as supermarkets; they are competing against cheap, imported Chinese fish and an already established market for captured fish. Lack of reliable data about production and markets, poor record keeping by farmers and the stagnation of the sector at the small-scale level have created barriers for potential investors and credit providers (Ngugi & Manyala 2009). These issues have therefore affected the robustness of the supply chain, the reliability of the institutional governance and the resilience of the innovation systems. In the coming chapters, these issues will be further explored.

4 Robustness of the supply chain

4.1 Introduction

The aim of this chapter is to provide insight into the supply chain's strengths, weaknesses, opportunities and threats (SWOT) in terms of economic, social and environmental sustainability. In line with the 3R proposal, robust supply chain integration is described as efficient and trusted interactions between the aquaculture sector partners that reduce transaction costs and risks for enhancing product quality and safety and reinforcing sustainability. An initial assessment of the robustness is derived from the SWOT analysis of the aquaculture stakeholders.

The aquaculture sector is characterized by lack of investment by the farmers and stagnated growth. The past efforts by the GoK, NGOs and bilateral and multilateral organizations to encourage growth have failed to ensure sustainability; the aquaculture supply chain is therefore not yet very robust. In this study, the focus was on the supply chain based on interactions between different supply chain stakeholders, ranging from input suppliers (fingerlings and feed) and finance providers, through to production and processing stakeholders and retail and trade enterprises.

The aquaculture supply chain map (Figure 5) shows the different stages in the supply chain, the stakeholders and the activities. It is an idealised aquaculture supply chain, since in reality some aspects may be missing. Alongside this exists an already established capture fisheries supply chain whose actors may also be involved in the aquaculture supply chain. While the aquaculture sector can benefit from interactions with the supply chain of the capture fisheries industry, particularly in the areas of logistics and infrastructure, most fish harvested from farms does not actually flow along the full chain. Most farmers sell their fish straight to the consumer without going through the steps of handling, processing and marketing. This is an advantage for farmers, because they avoid the brokers who are common in other agro-supply chains and who can dictate the price of harvests. The aquaculture supply chain is connected to other supply chains, such as the fish feed supply chain. This link is a prerequisite for the (sustainable) development of aquaculture in Kenya. It is also important to note that the fish feed supply chain is rather complex, because ingredients are sourced both locally and internationally (Rothuis et al. 2011).

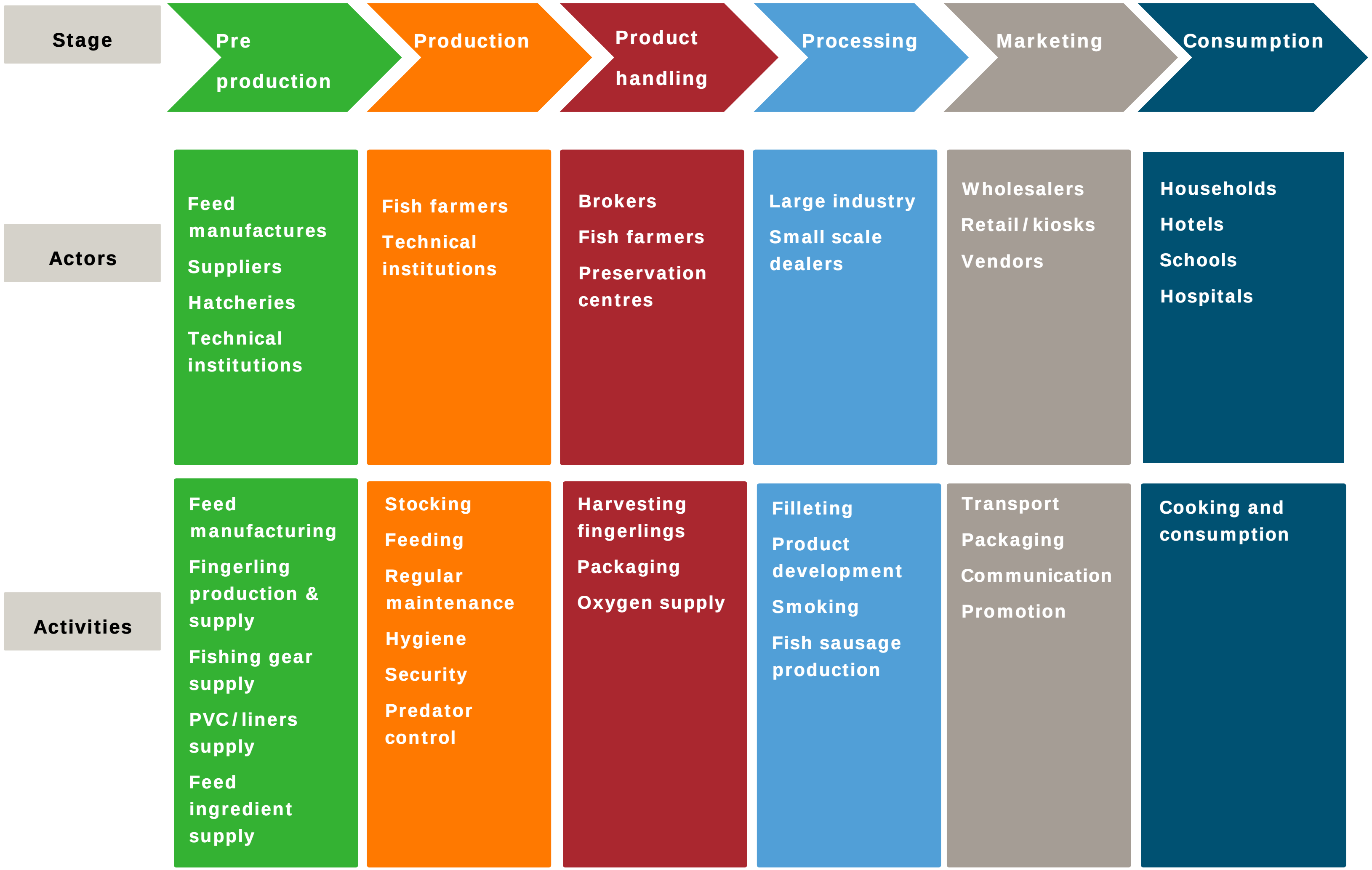

Figure 5 *The aquaculture supply chain*
Source: GOK and KENAFF (2014) edited by Wageningen Economic Research

4.1.1 Inputs

Until the initiation of FFEPP in 2009, the GoK played the greatest role in the pre-production stage, specifically in fingerling production. However, after 2009, demand for fingerlings increased beyond the capacity of National Aquaculture Research Development and Training Centre (NARDTC) and the other GoK centres spread across the country. Therefore the GoK had to accredit private fingerling producers so as to meet the fingerling demand. Universities have also contributed to production of fingerlings under research programmes. Farmers who are producing table fish can also produce fingerlings to sell to other farmers; therefore, fingerling production is also seen at production stage of the supply chain. Commercial fish feed producers are few, and this has led to unregulated production of fish feed, including home-made fish feed that is also sold to other farmers. Most farmers purchase their inputs straight from the suppliers (a list is given in Annex 5). Agrovet shops rarely stock fish farming supplies, and veterinary services for fish are lacking. Nevertheless, the Farm Africa aqua shop model has proved successful in making the pre-production stage vibrant in the western parts of the country.

4.1.2 Primary production

Most production is done by small-scale farmers. Product handling, processing and marketing are still very basic, and most farmers sell their unprocessed products at the farm gate, bypassing all the post-harvest stages.

4.1.3 Processing and marketing

Since there is little activity currently at the processing and marketing stages, the Aquacultural Association of Kenya (AAK) has been actively involved in linking farmers to processors and markets and to training opportunities on quality control and value addition.

4.2 Economic sustainability

The following issues affecting the economic sustainability of the aquaculture supply chain were identified during the course of the investigation:

- Quality and quantity of inputs
- Low fingerling production versus high demand
- Challenges in reproduction and inferior breeds
- Feed issues: quality, ingredients, lack of commercial supply
- Need to improve fish feed
- Stagnation of the sector
- Lack of credit availability
- Lack of market access, market demand for fish and fish prices
- Lack of entrepreneurial skill at the farm level.

These issues are briefly discussed below.

4.2.1 Quality and quantity of inputs

Despite the robust demand for tilapia and catfish fingerlings, there is a lack of robustness in the quality and availability of fingerlings and feed to fish farmers (Rothuis et al. 2011). Studies show that the most important inputs in aquaculture in Kenya are fish feed and fingerlings, particularly fish feed, which accounts for more than 50% of the total operating cost (Liti et al. 2005). The growth of the aquaculture industry is positively correlated with the increased use of quality feed that meets the nutritional requirements of the cultured species; this is corroborated by most Kenyan fish farmers, who mention fish feeding and feed management as their major challenge (Munguti et al. 2014b). The low quality and quantity of fish feed and fingerlings has been a limiting factor in the growth of the sector, compromising the aquaculture supply chain and resulting in inferior products and high production costs because of inefficiencies in production. Prior to the FFEPP, farmers mainly relied on the GoK for tilapia and catfish fingerlings produced at the NARDTC and other GoK facilities spread across the country. The supply of adequate quality feed was much more limited, with many feed mills opting to produce feed targeting other livestock production systems. The result is that farmers formulate their own fish feed using rudimentary technology and raw materials mostly from agricultural by-products from their farms.

4.2.2 Low fingerling production versus high demand

In 2009, the FFEPP triggered short-term demand for 28 million tilapia and catfish fingerlings, which was followed by a ripple effect demand for 100 million fingerlings. This demand could not be adequately supplied, even by the private sector. The GoK therefore requisitioned several of its facilities across the country to supply fish feed and fingerlings. Unfortunately, since most of the GoK facilities lack basic equipment and people with the necessary skills, this move failed to effectively increase supply of the required inputs (Munguti et al. 2014a). Some farmers had to leave farming in the first phase of FFEPP due to inconsistency in availability and poor quality of fingerlings. The private sector has thus had to meet the increased demand for fingerlings, but this has created serious quality issues (Shitote et al. 2013).

4.2.3 Challenges in reproduction and inferior breeds

The reproductive biology of tilapia and catfish poses more problems. Tilapia is a prolific breeder; in contrast, without hormonal treatment catfish does not breed in captivity. Catfish eggs and fry are more vulnerable than tilapia eggs and fry and need protection from aquatic predators, especially tadpoles, to achieve high survival rates. Tilapia eggs and fry benefit from parental care and protection in the first weeks of their life (Ngugi et al. 2007).

Due to the prolific breeding of tilapia, farmers are advised to stock an all-male tilapia population. As achieving 100% male populations in breeding programmes in Kenya is still a problem, farmers are advised to stock their tilapia ponds with catfish fingerlings (5–10% of the number of tilapia fingerlings), which will control the tilapia population (Ngugi et al. 2007). Farmers who stock their ponds with mixed sex tilapia – either knowingly or unknowingly – when they purchase fingerlings from unscrupulous breeders end up with fish breeding in the ponds. The offspring consumes part of the feed intended for the initially stocked fish population. This leads to production of stunted fish. If the fish do not attain market size (250–300 g), farmers may have to sell the fish for a lower price (Ngugi et al. 2007). Farmers interviewed during the quick scan and those who attended the workshop lamented that they purchased what they were assured were all-male tilapia fingerlings, but they ended up with a mixed population that took longer than 6–8 months to reach market size. This has caused serious trust issues between the farmers and the fingerling providers. Note that this long period to reach table size may also relate to issues such as low quality of fingerlings and lack of proper pond and feed management. Unfortunately, the importation of Super YY tilapia males as a solution to prolific tilapia breeding is still in its early stages, as few private hatcheries are importing the breed. The handling of this breed is not mentioned anywhere in the policy documents or legal framework.

The fact that in Kenya catfish has other uses apart from food has raised the demand for its fingerlings. Catfish fingerlings are bought to be used in controlling the prolific breeding of tilapia in fish ponds, to control snails in rice paddies and as bait in capture fisheries. This, coupled with the initiation of the FFEPP in 2009, increased the demand for the catfish fingerlings. Munguti et al. (2014a) estimate annual demand for catfish fingerlings at 100 million fingerlings per year.

Scarcity of fingerlings, few facilities producing fingerlings and low trust of farmers in the quality of fingerlings mean that farmers travel long distances to purchase fingerlings from what they deem to be a good source. This increases the cost of production and may also stress the fingerlings, which are packed in plastic bags with water and oxygen that is expected to last for up to six hours. Some farmers travel distances that take longer than six hours with bad roads and under hot and stressful weather conditions with fingerlings that may not have been conditioned properly in the hatchery. The consequences are often higher fingerling mortality rates. When individuals purchase fingerlings, especially over long distances, it can be costly; when clusters of farmers or cooperatives make these purchases, the cost of transport becomes cheaper. One such arrangement is conducted by the extension office in Nakuru County to help groups of farmers from Njoro area purchase fingerlings from Homa Bay, a distance of more than 300 km. While the scarcity of fingerlings could be seen as a challenge, it is actually an opportunity for entrepreneurs, especially youth eager to learn existing and new technologies in fingerling production. Despite the GoK now having standards to verify fingerling producers, including monitoring and evaluation criteria, there is still no significant improvement yet, which limits robustness in the supply of fingerlings.

Poor handling of fingerlings in hatcheries and stressful conditions during transportation have often contributed to significant mortality during transportation, stocking and in the period after stocking. Florio et al. (2009) conclude that overcrowding and poor water quality in hatcheries potentially predispose tilapia to protozoan and monogenean ectoparasites. Some farmers have reported losses of 50% of fingerlings between the day of stocking to the fifth day, due to parasitic infections and stress from transportation over long distances.

In addition, a link has been established between parasites on birds that are fish predators and farmed tilapia in earthen ponds. The birds, such as heron, either act as vectors of fish parasites or inflict injuries to the fish, creating opportunities for secondary infection (Gustinielli et al. 2010).

4.2.4 Feed quality

The critical importance of tilapia and catfish feed in the Kenya aquaculture supply chain has been emphasized by different authors (Liti et al. 2005, Ngugi et al. 2007, Shitote et al. 2013, Munguti et al. 2014a). The consistent supply of good quality feed in sufficient quantity is compromised by several factors, the biggest among them unscrupulous fish feed manufacturers who produce feed of low quality and sell it to farmers. On the other hand, importation of raw materials increases the price of feed, making it beyond the reach of the small-scale farmer.

4.2.5 Feed ingredients

The bulk of materials used in fish feed production are waste products from agricultural production of human food, such as maize bran, rice bran, wheat bran and sunflower cake. These crops are produced as rain-fed agriculture with yields depending on weather conditions and affected by climate change. These ingredients also face competition from other livestock production systems, mainly poultry and dairy feed production. Also, these single-ingredient feeds are deficient in macro- and micronutrients and have anti-nutritional factors and poor palatability, leading to low fish growth that limits fish yields (Munguti et al. 2014b). Issues regarding quality, quantity, timely supply and affordability have affected the robustness of the supply chain. An inventory by Gitonga (2014) shows that there are numerous livestock feed manufacturers, but very few have taken up fish feed manufacture. Scarcity of fish feed limits timely supply to the farmers. In addition, since some of the materials (e.g. cotton seedcake) are sourced from the neighbouring countries, specifically Uganda and Tanzania, the cost of feed production goes up, making it unaffordable to the small-scale producer (Nalwanga et al. 2009).

The FFEPP triggered an increase in demand for feed from about 10,000 tonnes to about 50,000 tonnes/year (Munguti et al. 2014a); the lack of fish feed was a key challenge in the FFEPP implementation, because the lack of established fish feed manufacturers meant that farmers had to make feed themselves, and it was of poor quality due to the poor quality of ingredients used (Gitonga 2014).

At the time of the quick scan, it was established that there are a few animal feed manufacturers exploring investments in specialized manufacturing plants due to the demand in fish feed. An interview with Mr. Kitesh of Sigma Feeds established that his facility was installing equipment to produce floating tilapia pellets. In addition, Unga Feeds was also setting up a fish feed production line in its facility in Nairobi. Also, since GoK anticipates growth in the livestock industry due to increased demand for animal protein, it is supporting the growth of animal industry through policy (MOALF 2014), pushing for the enactment of the proposed Livestock Act, updating the Fertilizer and Animal Foodstuffs Act and encouraging cooperative societies and farmers groups to establish feed production plants in order to increase availability and access. Despite the presence of the Kenya Bureau of Standards (KEBS: a statutory body charged with enforcement of standards and certification), there is still a challenge in ensuring quality of animal feed in the country, particularly of fish feed. Smaller feed processors are unregistered, unregulated and difficult to trace, therefore evading the oversight of KEBS. Furthermore, most feed ingredients are not fully standardized, so manufacturers have challenges in complying with set overall feed standards (Gitonga 2014).

Since production has stagnated at small-scale level, farmers find commercial feeds expensive. Despite their efforts to produce their own feed, farmers are unable to make the feed required for the different stages of fish development; this has become a pressing issue in the growth of Kenyan aquaculture. Farm feed is formulated by mixing ingredients to make a balanced diet. In Kenya, the most-used animal ingredient in fish feed for tilapia production is fish meal. Common ingredients include Omena (*Rastineobola argentea*) and freshwater shrimp (*Caridinea niloticus*) which is a by-product of Omena fisheries in Lake Victoria (Liti et al. 2005). The availability of the freshwater shrimp and Omena from the natural aquatic environment is also affected by overfishing, infestation of the Lake Victoria with aquatic weeds and habitat degradation, as well as the fact that Omena is used a source of cheap animal protein by poorer people in Kenya (MOALF 2013a).

4.2.6 Lack of commercial feed

Most animal feed processing firms have avoided producing commercial fish feed because very few farmers can to buy it, since fish farming has stagnated at the small-scale level. At this level, farmers are encouraged by extension officers to fertilize the ponds using organic manure and/or inorganic fertilizers to encourage growth of natural feed (zooplankton and phytoplankton) in the ponds and then supplement it either with formulated feed or single ingredient feeds such as maize bran, wheat bran or rice bran (Ngugi et al. 2007). The feed manufacturing firms therefore produce feed on demand for the few intensive commercial fish farms.

4.2.7 Improving fish feed

After FFEPP was launched, unscrupulous fish feed manufacturers took advantage of the fish feed scarcity to sell feed of compromised quality. Despite national standards for fish feed being established to control this, they have been difficult to implement and enforce (Munguti et al. 2014a). In fact, a survey of the quality of feed available in the market both from private manufacturers and GoK agencies established that the protein content of fish feed fell below standards recommended by GoK for tilapia and catfish production. The study established that even when fish feed packaging indicates that it contains the recommended level of protein, the feed actually contains less and is therefore inappropriate for use for fish production (Shitote et al. 2013). Further studies show that this problem is common in East Africa, where there is evidence of substantial differences between labelled and actual nutrient contents for fish feed. This problem was traced to the quality of ingredients used in the manufacture of fish feed.

Unfortunately, less attention has been directed towards understanding the impact of handling and processing feed components on the nutritional quality and relative nutrient costs along the supply chain compared to the attention directed towards developing suitable feed and potential feed components (Nalwanga et al. 2009). Studies conducted on ingredients used to formulate commercial fish feed from around Lake Victoria show a significant decline in the nutritive content (most importantly protein) from primary source outlets to outlets positioned downstream in the supply chain. The investigations show that ingredients from fish landing sites and oil mills have better nutritional quality than those from stores and shops, and that this is due to deliberate contamination to increase weight: most likely by inorganic materials such as sand. Additionally, despite the decrease in the nutritional quality of feed ingredients, the cost per kilogram of an ingredient increases between different outlets resulting in disproportionately increasing costs per unit of nutrient along the distribution chain (Nalwanga et al. 2009). Farmers are forced then to buy expensive good quality commercial fish feed, which may not be cost-effective in small-scale production systems. Furthermore, farmers who do use good quality ingredients to make fish feed on their farms still end up with poor quality feed due to inadequate feed processing, resulting in the feed sinking. With sinking feed it is difficult to establish whether sufficient feed has been given and whether all feed is consumed. The result may be under- or overfeeding, the latter meaning loss of unconsumed feed on the pond bottom. Both over- and underfeeding result in high feed conversion ratios (FCR) (Munguti et al. 2014b). Given that most of the raw materials for commercial feed production are imported and the costs of production are high, feed is expensive for small-scale, low-income farmers. This discourages most feed manufacturers from producing animal feed in general.

4.2.8 Stagnation of the sector

The aquaculture sector in Kenya lags behind developments in other parts of the world and even further behind the sectors in Nigeria and Egypt, where there has been great advancement in fish production as a result of hybridization, genetic selection, application of all-male tilapia culture, formulated diets, biofloc technology ponds, cages, tanks and recirculation systems. Small-scale fish farming is challenged by increasing competition for land and water, lack of efficiency in the supply chain and relatively high production costs, all of which suggest that a shift from small-scale production towards intensification is necessary (Munguti et al. 2014b). Fish farming in Kenya, however, is stuck at low levels of intensity, except for a few farmers on the outskirts of major towns and cities who practice production in recirculation systems (motivated by high production capacities in a small area). Kaliba et al. (2007) report that a pond manager spends about 20–80 hours a year managing a 200 m^2 fishpond (which is the average fishpond used in small-scale production systems) at a cost of KES 4,279/month. The authors establish that producing tilapia using borrowed capital and rearing the fish in a 200 m^2 fishpond is not as economical as in a fishpond larger than 600 m^2. In addition, when farming takes place in ponds larger than 600 m^2, rearing the recommended all-male tilapia population increases gross profit margins. Intensive fish farming is unpopular with most fish farmers due to the high cost of investment and operational costs. This is evident based on the scarce data available on production of tilapia and catfish from cages, recirculation systems and raceways in Kenya (Munguti et al. 2014a). There is a great opportunity for cage fish farming in Lake Victoria and Lake Naivasha, but at the moment there are only a few businesses, such as Lake View Fisheries Limited, farming in selected parts of Lake Victoria. Also, production in lakes is limited due to regulations from GoK agencies such as the National Environment Management Authority (NEMA) and Acts such as the Environmental Management and Coordination Act (EMCA). Pollution of the lakes with nutrients and pesticides from the catchment limits the areas where cage culture can be practised. In addition to this, the two lakes have a serious infestation of aquatic weeds, most prominent among them the water hyacinth (*Eichhornia crassipes*) (Munguti et al. 2014a).

4.2.9 Lack of credit availability

Another factor that explains the stagnating sector is the lack of access to credit facilities such as loans for aquaculture activities. Most financing institutes consider fish farming a high-risk activity. Also, the provision of credit is limited by the fact that small-scale farmers do not have bank accounts (Ngugi & Manyala 2009).

4.2.10 Lack of market access, market demand and fish prices

Markets for farmed fish are not robust, even though there is potential for increased demand because catches in the capture fisheries are dwindling. There are several reasons why a market for farmed fish has been difficult to establish, including:

- low value addition initiatives
- inability to sustain consistent production
- weak product-marketing strategies.

Though it is believed that farmed fish can compete favourably in the market with capture fish, what consumers actually want is not properly known, and fish and fish products that target different market segments require different handling, processing and packaging. In addition, the market segmentation for farmed fish is less well understood than that for capture fisheries (Ngugi & Manyala 2009). One of the bottlenecks that limit the marketing of aquaculture products is the relative ignorance of the Kenyan consumer when it comes to particular fish species. Sometimes consumers are sold fish species that are incorrectly labelled as tilapia; this creates a negative image if the fish consumed does not live up to the expectations. Also, value addition by traders such as fishmongers is limited, as are consumer fish preparation and cooking skills (Rothuis et al. 2011).

Lack of cold storage facilities to store fish after harvest has limited marketing of farmed fish. Since fish is a highly perishable commodity, farmers risk losses if they harvest all their fish from their ponds without a ready market. Unlike the captured fish market, where processing – such as smoking – to increase shelf life takes place at the lakeside point of capture, in the farmed fish supply chain the fish processing segment is not well established. Despite the high demand for fish, market linkages for farmed fish are not as established as they are in the horticulture and dairy milk supply chains. Farmers therefore need to focus on high potential market areas. Studies show that in the top 10 fish farming countries in the world, small to medium enterprise fish farming success is due to strong markets; access to fingerlings, feed, credit and transport; and a focus on profits (Shitote et al. 2013). Challenges for markets in aquaculture are based on lack of market information; low value addition strategies; threats from imported fish, particularly from China; competition from capture fisheries; and inability of farmers to consistently produce enough fish to sustain market demands.

Currently the demand for fish in Kenya is mostly being met by capture fisheries, which contribute 86% of the total fish production in the country (MOALF 2013a). It is a challenge for fish farmers to enter and sustain production for these markets. The niche that fish farmers could occupy – supply during the closed season – is also difficult to access, as farmers in some areas have to compete with illegal fishers who poach during the closed season and sell their fish very cheaply. This is common around Lake Naivasha (interview with Ms Phoebe). Rothuis et al. (2011) identify market segmentation for fish ranging from rural to urban, low income to high income and from low consumption to high consumption and even tourists. For low income segments in urban areas (often slums), relatively small portions of fish (100– 150 g) are preferred. People buy either whole, small tilapia or small pieces of tilapia or catfish. On the other hand, middle income families will prefer size ranges of 250–350 g, while high-end markets will prefer sizes above 350 g. Prices can go up to USD 1.87/kg in major cities such as Eldoret and other parts of the country; and for major towns surrounding the aquaculture production centres, markets for fish are assured (Quagrainie et al. 2010).

Given that small-scale production is done in cycles of 6–8 months, it is difficult for farmers to maintain a regular supply of fish – especially when they do not have cooling facilities. In addition, there is no contract farming similar to that common in sugar and rice farming. Farmers have been encouraged by the GoK and NGOs to form clusters from which they can increase production via shared learning and common purchase of inputs. Cluster farmers have been helped by the AAK to link to markets in urban centres. When organised in clusters, the farmers can plan the stocking, production and harvest to ensure consistent supply of fish once market linkages have been made. Learning institutes and health facilities can provide regular markets as long as (clusters of) farmers can maintain production and a regular supply (Kimathi et al. 2013). In addition, forming of clusters is an opportunity for farmers to have joint investments in cold storage or processing facilities as well as marketing through gathering and sharing price information. However, it is important that farmers start viewing aquaculture as a commercial activity instead as a subsistence activity (Rothuis et al. 2014).

4.2.11 Lack of entrepreneurial skills at the farm level

Lack of entrepreneurial skills at the farm level can be linked to the general challenge of limited knowledge of aquaculture investment that afflicts the Kenyan aquaculture industry and the lack of information on the economic performance of the various fish farming systems (Munguti et al. 2014a). In addition to this, weak extension services have contributed to farmers failing to have the basic skills in entrepreneurship. Because many farmers started fish farming with the help of free inputs provided by government programmes or projects, many current farmers do not have a business-like approach to the activity. Despite AAK providing a platform for training farmers on important aquaculture aspects, entrepreneurship in the Kenyan aquaculture sector has been minimally explored. However, there are some cases where farmers have explored fertile areas for entrepreneurship, including fingerling production, value addition and marketing.

4.3 Environmental sustainability

The following issues affecting the environmental sustainability of the aquaculture supply chain were identified during the course of the investigation:

- Geography and climate
- Eutrophication
- Chemicals and drugs
- Non-indigenous species
- Water scarcity and floods
- Waterborne diseases.

The impact of aquaculture on the Kenyan environment has received little attention in the literature since the current level of small-scale production generally has low environmental impact. However, as the sector grows from extensive, non-commercial through to more intensive, commercial aquaculture there will be increased use of feed, fertilizers, drugs and chemicals. Release of water with elevated nutrient levels and even drug and chemical residues drained from earthen fish ponds into natural water bodies after fish harvests is an issue of concern in countries where intensive fish farming takes place. This may also become a growing issue in Kenya when the sector intensifies and expands. Increase in production may also have impacts on water usage, which will open avenues to conflict about water resource use with other agricultural activities and other water resource users. On the other hand, water drained from fish ponds can be a source of enriched (fertilised) irrigation water for agriculture.

4.3.1 Geography and climate

Not all locations in Kenya are suitable for aquaculture, due to their geographic and climatic conditions. In some areas (e.g. the Mara River basin in the south-west), ponds have been constructed at high altitudes, which are subject to low temperatures that negatively influence the growth of tilapia. Water availability can be an issue in dry areas, for example in the north-eastern part of the country (Hennen & Bolman 2015). Also, water availability is influenced by other uses, such as agriculture. For local feed production, agriculture is of major importance. If the trends of agricultural production over the period 2002–2012 are an indication for the next decades, it is likely that future agricultural production will fluctuate or even be erratic. This is related to rainfall: along the western rim of the Indian Ocean rainfall has diminished by approximately 15% over the period 2000–2015, dangerously affecting rain-dependent agriculture and thus food security (Funk et al. 2008). A further decline in rainfall in this area of East Africa is likely to occur in the future (Funk et al. 2008). Production uncertainty associated with rainfall variability remains a fundamental constraint to many investors (Cooper et al. 2008); in some areas, the impact of climate change may lead to abandonment of cropping altogether.

Another important factor is demographics. High population growth rates may almost triple the demand for food up to 2050. The consequence is more demand for land both from an urbanization perspective (in direct competition with land for earthen ponds) as well as from a food production perspective (Thornton et al. 2010). Moreover, for the last 30 years the average land holding has declined (ranging between 0.2 and 2.5 ha per capita) (Immink et al. 2001). When land sizes available for agricultural production are reduced, farmers must make sure their land is used for income-generating ventures. Based on the challenges of feed and fingerlings that discourage fish farming, farmers may opt for other agricultural production systems.

4.3.2 Eutrophication

Eutrophication (excessive nutrient load in water) is influenced by increasing populations, agriculture and industries. The management of the waste products of aquaculture production is key to the sustainability of the industry and to ensuring reduced conflict with other resource users. Aquaculture production interacts with natural water systems either directly or indirectly, and each affects the aquatic systems differently. Water from aquaculture production systems may be released into natural water systems, or farming in natural systems (e.g. by use of cages) introduces wastes into the water systems. For instance, studies show that cages used in rivers and lakes affect the water quality, as the cages release nutrient-rich waste (faeces, unconsumed feed and metabolic waste) into the water and underlying sediment. High concentrations of organic materials (feed, faeces) may cause, for example, modification of the macroinvertebrate community structure in the bottom below the cages: some species may disappear while the abundance of other species increases. When the amount of dissolved nutrients released to the environment reaches certain levels, phytoplankton blooming, increased turbidity, fluctuations in pH and dissolved oxygen can be the result. Elevated dissolved nutrient levels may lead to proliferation of macrophytic vegetation such as the water hyacinth (*E. crassipes*) in natural waters. This may in turn affect other aquatic organisms and also interfere with aquatic food chains. Unfortunately, compared to other countries where cage culture is well established, there is insufficient documentation to guide cage culture in Lake Victoria, although potential cage culture investors are already showing interest (Nabirye et al. 2012). It is clear that at Lake Victoria not all locations are suitable for future cage culture, due to eutrophication, lack of oxygen, and pollution (Rurangwa et al. 2016).

On the other hand, poor management of earthen ponds also leads to encroachment by macrophytes, which may provide habitat for snails. These are vectors for parasites causing bilharzia. Uncollected dead fish – apart from being sites for microbial activity – can contribute to nutrient loading and increased biological oxygen demand in the ponds. Furthermore, water discharged to rivers or lakes from earthen ponds during fish harvests contributes silt, nutrients and water with high biological oxygen demand (Larsson 1994). Pond discharge water can function as enriched (fertilised) irrigation water for agricultural fields.

4.3.3 Chemicals and drugs

Chemicals and drugs used in more intensive tilapia and catfish production that can be detrimental to aquatic life when poorly disposed of include hormones, flesh pigments, disinfectants and water treatment compounds. The use of these compounds in Kenya at current intensity and levels of production is believed to be very low. There is little data on the quantity of chemicals present in aquaculture effluents; however, with growth of the aquaculture industry, increased use of some of these chemicals should be expected. Disposal of chemicals after use poses great danger to other aquatic organisms. For instance, antibiotics have been found to take a long time to be eliminated from fish flesh (from a few days to several months). The most common drugs used in the tropics are formalin, potassium permanganate, diupterix and malachite green. Formalin, potassium permanganate and malachite green are used in dip baths for treating fish with parasites and fungus infections (Ngugi et al. 2007).

On the other hand, the use of methyl or ethyl testosterone in Kenya is well documented. The hormone is used in sex reversal of *O. niloticus* to achieve an all-male population by mixing it with feeds which are fed to fry (Ngugi et al. 2007). However, the documentation on how the chemicals should be handled and disposed of is often not available to the farmers. The disposal of these chemicals is a key concern because depending on how they are administered and disposed of, they can enter aquatic systems in many ways and kill or displace aquatic organisms. An example is in situ treatment of caged fish, which may result in chemicals being released into the environment and compromising the life of other aquatic organisms. Intensive aquaculture poses greater risks for disease outbreaks that can spread to wild populations or creation of resistant strains of human pathogens due to irresponsible use of antibiotics (which can result from lack of knowledge, awareness or concern) (Larsson 1994). Lastly, water quality may also be influenced by other industries, which potentially influences the aquaculture business. This applies particularly to potential future cage farming activities in Lake Victoria.

4.3.4 Non-indigenous species

The introduction of culture organisms into lakes, rivers and streams may threaten natural genetic resources; disrupt natural habitats by causing proliferation of vegetation or increasing turbidity; and introduce aquatic pathogens, predators and pests. Accidental introduction into natural systems of non-native fish from aquaculture production systems may cause serious problems in the receiving aquatic ecosystems. To protect the natural waters from introduction of non-indigenous species, the Environmental Management and Co-ordination Act of Kenya 1999 provides guidelines prohibiting and controlling the introduction of alien species into natural habitats (GoK 1999). However, this has not been effective in preventing infestation of Lakes Naivasha and Victoria with aquatic weeds such as *E. crassipes* and *Azolla*, because the infestation often took place before the guidelines were issued. The presence of large quantities of these weeds limits the exploitation of the lakes for cage aquaculture.

4.3.5 Water scarcity and floods

Demand for water – specifically water for fishponds – is a challenge for aquaculture given that Kenya is a water-scarce country. Reliance on rain-fed aquaculture means that robust production cannot be sustained. The annual available fresh water is 20.2 billion m^3; this water is also vulnerable to depletion, since the country is highly dependent on other forms of water use such as agriculture, tourism, livestock production and basic human health (Rothuis et al. 2011). Furthermore, Kenya experiences significant rainfall variability. Droughts are endemic and floods also occur frequently, and these extreme natural events have been blamed for farmers abandoning fish farming activities (Shitote et al. 2013). The use of water sources diverted from streams, run-off or floodwater risks contaminating the ponds with wild fish, parasites, polluted water and predators (Ngugi et al. 2007). Estimates show that demand for water for aquaculture is between 35,000 and 60,000 m^3/ha/year to maintain a depth of 1.5 m in a pond during the 240-day growing cycle and to counteract losses estimated at 1–2 cm/day (Larsson 1994). In the future, use of water for aquaculture may cause conflict with other resource users, particularly in times of water shortage.

On the other hand, fish farming can be integrated with agriculture, for example by growing fish in irrigation water reservoirs; this does not affect the quantity nor availability of irrigation water. Also, water drained from ponds is enriched with plant nutrients and can be used for irrigation. Especially in water-scarce countries such a double use of water is an efficient way of using this limited resource. In addition, crops can be grown in the pond bottom after draining the water, making use of remaining water and fertile sediments in the pond bottom.

The environmental impacts mentioned above and social issues affecting aquaculture development are addressed in FAO Guidelines for Responsible Aquaculture, and in FAO publications about aquaculture zoning and area management (Aguilar-Manjarrez et al, 2017; FAO 1997; FAO 2010).

4.3.6 Waterborne diseases

Although there are no reported cases linking aquaculture to waterborne diseases, the environment in which fish are cultured in earthen fishponds is likely to be a breeding ground for malaria and bilharzia vectors. Although tilapia and catfish may feed on the mosquito larvae and snails that are vectors for malaria and bilharzia parasites respectively, this may not be enough to control the outbreak of these diseases in cases of poor pond management. In addition, integration of fish and livestock production systems creates opportunities for the transfer of parasites from the livestock production systems into the fish production systems, which creates fish quality issues and public health challenges since the threats to public health from both aquaculture and livestock are diverse. Although common pathogens of warm-blooded animals do not generally cause disease in fish, the role of cultured fish in the possible transfer of pathogens between livestock and humans is important, especially in less developed countries. For instance, livestock faecal waste used as inputs in fishponds contains varying quantities of viruses and bacteria which can pose health risks to human beings. Studies in other countries have found that ponds fertilized with organic manure have faecal coliforms, salmonella and bacteriophages. Additionally, parasites such as trematodes, nematodes and cestodes may be transferred through livestock waste to aquatic plants and animals (Edwards & Little 2003). When infected fish is not properly cooked, parasites may be transmitted from fish to people (see, for example, Chai et al. 2005).

4.4 Social sustainability

The following issues affecting the social sustainability of the aquaculture supply chain were identified during the course of the investigation:

- Literacy
- Age
- Finance
- Perceptions towards eating fish
- Gender and youth.

4.4.1 Literacy

The uptake of extension information from extension officers is still low. Literacy issues prevent fish farmers from being able to improve their practices. This is despite the fact that the literacy rate in Kenya for people aged 15 and above is 84.5% (although there is regional disparity) (Rothuis et al. 2011). A study in Kenya showed that formal education positively correlates to adoption of technologies disseminated through extension (Kimathi et al. 2013). Most Kenyans have completed secondary school, and a small number have attained tertiary qualifications. Since most extension materials – pamphlets, newsletters, training sessions and seminars – are written or delivered in English, educated farmers are more likely to take up the information (Kimathi et al. 2013). The lack of information among farmers may stem from the burden on the scarce extension services and may explain why some farmers with good land that can be used for fish farming are not even aware of this potential (Shitote et al. 2013).

4.4.2 Age

Age may also limit people's ability to embrace new technologies. Ngwili et al. (2015) report a study in central and eastern counties where most people practising aquaculture were 45–50 years old. Fish farming was not a priority, but was carried out with other farming practices such as crop and livestock production. Most people were employed and were investing in agriculture as an activity to generate income after retiring from their job (Ngwili et al. 2015). This implies that younger farmers are not taking up aquaculture yet. Ngwili et al. (2015) show that younger people are more likely to take up or try new technologies and are also more capable of doing more laborious activities such as pond construction, pond repair and harvesting. The only time the younger generation were seen to be active in large numbers was when they were involved in pond construction in the FFEPP through the "Kazi Kwa Vijana" initiative (Ngwili et al. 2015).

4.4.3 Finance

There has been support from the GoK to the aquaculture sector specifically targeting small-scale aquaculture through subsidies, for example through the FFEPP (Munguti 2014a). However, investment and support from the private sector have been low, and it has been a challenge for small-scale aquaculture to get loans from financing institutions (Shitote et al. 2013). Rothuis et al. (2011) report the absence of credit providers in their visualization of the tilapia and catfish value chain and actually identify lack of credit as a major constraint to the growth of aquaculture. Even with the fact that credit is as important to intensive aquaculture as it is to semi-intensive and extensive aquaculture and that banks promise to fund different components of the value chain (start-up capital, processing, storage) as long as they are viable, farmers still find it a challenge to get credit (Rothuis et al. 2011). This is supported by a study by Quagrainie et al. (2010) who found that 24% of the fish farmers that took part in their study had used credit for their fish farm. The study was based on a survey among 131 fish farmers (69% from Western Province) that took place in 2005. Of the farmers that had used credit facilities 87% originated from Western Province (currently administratively devolved into Kakamega, Vihiga, Busia and Bungoma counties). Uptake of credit facilities by fish farmers in other parts of the country was far lower (only 9.7%). The low uptake of credit facilities was linked to a lack of knowledge on credit use among farmers and on the economic characteristics and potential of aquaculture among lending institutions, hence the need for the GoK agricultural lending agency (Agricultural Finance Cooperation-AFC) and other commercial agricultural lenders to invest in the enterprise. A new study on the uptake of credit among fish farmers after the FFEPP is needed to provide current data about credit uptake by fish farmers.

4.4.4 Perceptions towards eating fish

Factors influencing consumer choices with respect to both wild-caught fish and farmed fish include consumer perspective, price and cultural norms. Although fish provides a cheap and nutritious source of protein, some people in different parts of Kenya are still not assured of these benefits.

Cultural practices and beliefs influence dietary practices, and, in Kenya, fish eating and fish farming are limited due to cultural practices and beliefs: fish is a taboo food for the Maasai, and fish farming is limited by a nomadic lifestyle and by the belief that land is only for livestock grazing (Chege et al. 2015). For such communities, GoK programmes to encourage farmers to start fish farming have not been very successful. In these communities where traditionally fish eating did not occur, people were confronted with challenges such as marketing of the product and sustainability in fish farming.

Fish consumption is also affected by whether a man or a woman is controlling the income. When men from communities that did not traditionally eat fish control the income, fish will not be purchased as it is not part of the standard diet. However, when women have access to finances, they disregard these norms and include fish in their diet (Kimathi et al. 2013). That these traditions are changing and having less influence is also supported by the fact that most people eating fish are younger than 40. This group represents an important part of the demand in the aquaculture supply chain, and their eating habits are influenced by the knowledge that the white meat of fish is healthier than red meat from cattle, sheep and goats. It is also based on advice usually given to older men and women to change their diet by replacing red meat with white meat, specifically fish, when they are diagnosed with life-threatening diseases.

Preference for wild-caught fish depends on whether consumers come from a community of traditional fish eaters. Consumers living close to fishing areas prefer wild-caught fish for the taste. As reported by Obiero et al. (2014) sources of fish in the market depend on whether a region is close to a natural water body; for instance, markets close to Lake Victoria are dominated by wild-caught fish, and markets in areas far from natural water bodies have mostly farmed fish. Reports about consumer preference for caught fish over farmed fish are contradicting. Obiero et al (2014) reports that people who are concerned about food safety and quality standards would prefer farmed fish over capture fish, due to concerns about pollution residue. On the other hand, Little (2004) states that some consumers may choose not to eat farmed fish due to the use of hormones in sex reversal of tilapia, combined with fear for potential contamination due to the use of pesticides. Fish traders also vary from region to region. For instance, in the central part of the country, consumers buy fish from vendors, hawkers, open fish markets and farm gates, buying very little from wholesalers. In the western part of Kenya, most fish purchases are made at open markets and vendors, and very few people buy from farm gates. This shows that there is little preference for farmed fish by consumers in the western parts of Kenya as compared to the central part of Kenya based on proximity to wild-caught fish (Obiero et al. 2014).

When it comes to prices, consumers are willing to pay more for wild-caught fish than for farmed fish products. However, the price premium for wild-caught fish may decrease as people become more familiar with cultured species (Musa et al. 2014). Of the farmed fish, consumers will pay more for tilapia than for catfish (Kimathi et al. 2013, Musa et al. 2014, Obiero et al. 2014). Most consumers prefer fresh fish over fried, filleted, dried or smoked fish or previously frozen fish.

Fish consumption patterns are shifting from being dominated by tradition and proximity to fishing areas to fish availability and taste. Furthermore, demand for fish is rising due to the growing population and the changing eating habits among Kenyans as they move from eating red meat to white meat, which is considered healthier. In general, the demand for fish in Kenya can be marked as robust; however, for specific groups and areas there are definitely issues that limit the demand for (farmed) fish. Fish consumption is significantly related to household size, income, education and religion; for example, Seventh-Day Adventists do not eat catfish (Obiero et al. 2014). But since studies show that fish characteristics such as overall quality, ready availability and taste have the greatest influence on consumer preferences, these qualities need to be stressed for improved marketing through a target-oriented approach to existing customers and attracting new consumers for market penetration (Obiero et al. 2014). Despite increased aquaculture adoption and subsequent increase in fish supply in the country, not enough is known about consumer preferences for farmed fish products, which may hinder optimization of production and marketing of the aquaculture sector.

4.4.5 Gender and youth in aquaculture

Whether men or women own the land has implications for aquaculture. Kimathi et al. (2013) report that in the FFEPP, most fish farmers were men; this was because for someone to be involved in the programme they had to own land, and most of the landowners were men. Youth and women may therefore have limited opportunities to take up aquaculture production, given their lack of land ownership. Yet small-scale aquaculture activities are more successful when carried out by women, and especially by those farming in clusters. Youth and women form groups and carry out fish farming in reservoirs or dams that are community-owned (interview with an extension officer attached to Njoro Office of Nakuru County). Ngwili et al. (2015) report that in Machakos and Kiambu there is a near gender balance in fish farming. The study revealed fish farmers in the two counties to be 80% men and 74% women respectively.

Studies also show that more women than men suffer from poverty, and that female-headed households are more prone to poverty than male-headed households (Rothuis et al. 2011). Men are attracted to the fish farming sector if profits can be made (Immink et al. 2001). In fact, as fish supply chains become more international, gender roles in the aquaculture supply chain are becoming disrupted. Traditionally female roles of purchasing fish are diminishing, and women are now more involved in the peripheral parts of the supply chain such as fish trading and processing. As men enter the fish processing business, they may continue to displace the role of women (Obeiro et al. 2014).

Table 1 *SWOT robustness of the supply chain*

	Strengths	Weaknesses	Opportunities	Threats
Economic sustainability	Marketing chains for farmed fish are short (producer–consumer), hence eliminating intermediaries; farmed fish prices compete with those from the capture fisheries; increasing entrepreneurship, especially among fingerling producers; high demand for fingerlings (tilapia and catfish)	Unscrupulous entrepreneurs producing feed and fingerlings; little value addition (fish sold fresh); short shelf life; farmers lack knowledge and skills for fish breeding and farm management; scarcity of and poor quality fingerlings; lack of enough extension services/functionaries; poor documentation and reporting; poor record keeping by farmers; low quality and expensive fish feed; lack of technology adoption due to lack of popularity; waste of feed resulting in poor FCRs and higher costs of production	High demand for fish; fish production from Lake Victoria in decline; higher prices of captured fish; cage farming in lakes and reservoirs; value addition to increase shelf life; cluster farming and formation of cooperatives; farming of other potential species, e.g. common carp; potential to explore mariculture; bait fish production; development of standards on feed and fingerling quality; loans from banks and microfinance institutions; increasing population; increasing per capita GDP; increasing urbanization	Cheap fish imports from China; competition from capture fisheries; competition from other sources of animal protein
Environmental sustainability	Availability of resources such as water and land; favourable geographic and climatic conditions in some parts of Kenya; clay soil in some parts, making pond construction easier	Most aquaculture depends on both rain and natural water supply (springs and rivers, which are prone to pollution and scarcity of water); intensive farming could lead to high nutrient loads and pollution from fertilizers and feed, resulting in eutrophication and lower water quality; contamination from pesticides	Using natural solutions to filter water, e.g. wetlands, grassland, etc.; potential for cage culture in lakes, reservoirs and dams	Unfavourable geographic and climatic conditions in some parts of Kenya, e.g. some parts of Lake Victoria are not suitable due to eutrophication and lack of oxygen; pollution; drought; conflict in resource use; spread of diseases and parasites in integrated systems
Social sustainability	Aquaculture sustains livelihoods of the rural poor; positive impact of fish on human health; the sector provides employment; high demand for fish by consumers; more youth eating fish; high literacy levels	Non-fish-eating communities; consumer perceptions based on religion, e.g. catfish eating; poor quantification of the socioeconomic contribution of the sector; few women and youth in aquaculture; cultural bias in land ownership by women and youth	Promotion of eating fish by the GoK; segmentation of markets (low income, middle income and high income buyers in the urban areas)	Lack of investment; low levels of fish consumption in many parts of Kenya; few youth and women in aquaculture; low land ownership by women; lack of consumer awareness of fish species

4.5 Recommendations

This chapter contains an analysis of the supply chain's strengths, weaknesses, opportunities and threats in terms of economic, social and environmental sustainability. The recommendations for more robustness in the aquaculture supply chain are to:

- Identify a working business model for Kenyan aquaculture that will move the sector from its current state to medium- and large-scale commercial farming where all elements of the supply chain are robust.
- Strengthen enforcement of standards to curb poor quality of local feed and fingerlings. KEBS urgently needs more capacity to do this
- Support and promote cluster faming among farmers, which gives them more bargaining power when they purchase inputs and invest in cold storage, processing and marketing
- Improve the skills and practical knowledge of farmers in aquaculture, with special attention and help given to women and youth, to form groups so they can take up fish farming. In such groups, the practical knowledge and skills of farming and marketing can be taught. This can be done by increasing the funding of training and extension programmes.

5 Reliability of institutional governance

The aim of this chapter is to provide insight into the strengths, weaknesses, opportunities and threats in terms of the reliability of institutional governance of aquaculture in Kenya. Reliable institutional governance refers to public–private cooperation, co-innovation and a public economic policy framework that supports private investment and enhances opportunities for (inter-)national trade (Wageningen UR 2015). This chapter focuses on how policies, standards, laws, regulations and markets are supporting aquaculture in Kenya from a business perspective: that is, the degree to which they provide an enabling environment for private investment and enhance trade opportunities. Compared to agriculture and animal husbandry, aquaculture is a relatively new and unknown activity in Kenya. In developmental strategies it has not received a high priority; as a consequence, aquaculture development is lagging behind the development of other agricultural sectors.

Opportunities and constraints that influence the reliability of institutional governance can be divided into the following three categories:
1. Reliability of policies and regulations
2. Reliability of economic transfers
3. Reliability of soft instruments.

The issues related to these three categories are briefly discussed below.

5.1 Reliability of policies and regulations

This section focuses on the degree to which the reliability of policies and regulations provides an enabling environment for private investment and enhances trade opportunities.

In the past, aquaculture received little or no attention in the National Development Plans, despite Kenya taking a systematic approach to planning and development in all sectors since independence. Policy development in aquaculture relies on other overarching policies, such as the Economic Recovery Strategy (ERS) for Wealth and Employment Creation 2003–2007 and the Strategy for Revitalising Agriculture (SRA) 2004–2014. However, despite this apparent formal support, aquaculture still receives little attention even in discussions about natural resources and environmental management. This originates from a lack of understanding and prioritization for aquaculture at government level, hence responsibility for aquaculture is moved around the departments and ministries (Ngugi & Manyala 2009). The only time fisheries (and by extension the administration of aquaculture developments) was a stand-alone ministry was in 2007. The Ministry of Fisheries Development was created to prioritize aquaculture in the State Department of Fisheries; however, the department was grossly understaffed (Ngugi & Manyala 2009).

It is also important to note that GoK has been preparing four-year National Development Plans to stimulate growth across *all* productive sectors. While these documents highlight issues that are relevant to aquaculture, they have fallen short on specifically elaborating the role of aquaculture in the economy. The documents describe the dwindling production from the natural waters and suggest the option of aquaculture, but give unattainable production projections from the sector.

The aquaculture sector falls behind dairy and horticulture in development despite them all coming under the same department, the Ministry of Agriculture, Livestock and Fisheries (MOALF). MOALF has decent sector development strategies that have contributed to growth in other sectors. For instance, while developing the National Aquaculture Policy (NAP-2011), GoK recognized important MOALF development strategies and policies such as the National Agricultural Research System Policy (NARSP-2008), Agricultural Sector Development Strategy (ASDS-2008) and the National Agricultural Sector Extension Policy (NASEP-2007) (MOFD 2010). However, while these policy documents are effective in other agriculture sectors, their success has not been seen in aquaculture. The weak institutional framework has prevented aquaculture from benefiting from some important programmes that are supposed to encompass all sectors in the MOALF. For instance, the Agricultural Sector Development Support Programme (ASDSP) has been key in guiding partnerships in the agriculture sector. It has been influential in reducing mistrust among the diverse partners (i.e. GoK agencies, private sector stakeholders and civil society organizations) in the agriculture supply chains by providing guidance on collaborative partnerships principles (MOALF 2013a). Yet the impact of ASDSP in the growth of aquaculture has been minimal. One of the possible causes is that the administration of extension in aquaculture was included under livestock in the National Agriculture and Livestock Extension Programme (NALEP), implemented mainly by the Department of Agriculture and Livestock Development, rather than the Department of Fisheries, which looks after the development of the aquaculture sector (Ngugi & Manyala 2009). This shows a great misunderstanding of where and how administration of aquaculture should be carried out.

The following opportunities and constraints influence the reliability of policies and regulations:

- Out of date
- Lack of implementation
- Lack of reliability
- Lack of consistency
- International compliance.

These opportunities and constraints are briefly discussed below.

5.1.1 Out of date

The State Department for Fisheries and Blue Economy (SDFBE) is responsible for the development and implementation of policy. In general, aquaculture development is driven and regulated by these policy documents and regulations:

- National Oceans and Fisheries Policy (NOFP) of 2008
- Agriculture Fisheries and Food Authority Act No 13 of 2013
- Food and Agriculture Organization (FAO) Code of conduct for responsible fisheries
- Fisheries and Oceans Policy 2008
- NAP-2011
- National Development Plans
- The National Food Policy
- Poverty Reduction Strategy Paper
- Environmental Management and Coordination Act (EMCA)
- ERS for Wealth and Employment Creation 2003–2007.

However, aquaculture is currently operating without a specific policy, as the NAP-2011 time frame has expired. The National Aquaculture Strategy and Development Plan (NASDP 2010–2015) is still a draft and was never completed. The Plan expired in 2015 and is supposedly under review. There is no information on the current status of review of the two documents, so the sector has fallen back to using the NOFP of 2008.

Despite the numerous policy documents and legislation in aquaculture development, there is still no reliability in institutional governance of the aquaculture sector. On paper, the above-mentioned documents cover critical issues in reliability of institutional governance (MOFD 2008, 2010). The policies also guide legislation, for instance by seeking to review existing statutes to eliminate areas of conflicting interest. However, the implementation of the policy documents and legislation has been compromised by low funding, low human capacity and inadequate political support (MOFD 2008). Also, policy and regulations for aquaculture are scattered, generic and, in some cases, not practical. In these documents, aquaculture receives little attention and many of the critical development issues are not addressed (Ngugi & Manyala 2009). Many GoK agencies have infrequent interaction with aquaculture stakeholders in Kenya, probably resulting from a lack understanding of the priorities of the sector. One possible cause for this lack of understanding is that many GoK agencies place more emphasis on capture fisheries than on aquaculture.

GoK has identified strategies that are appropriate for reliable institutional governance in the NASDP 2010–2015, which include developing appropriate legislation and regulations, developing a one-stop shop for investors, improving statistics collection and information sharing, increasing participation by women and youth in aquaculture, developing guidelines for responsible aquaculture and ensuring increased investment (MOFD 2010). However, while these strategies appear comprehensive, they have not been implemented.

5.1.2 Lack of implementation

Due to being moved from one ministry to another, departments dealing with aquaculture development have undergone frequent restructuring to accommodate the ever-changing mandates. Currently the GoK administers the aquaculture sector through the SDFBE, which is one of three departments in the MOALF. There is a single directorate in the SDFBE called the Directorate of Aquaculture and Technology Development (DATD) that manages both research and extension, as opposed to a previous arrangement where there was a Directorate of Aquaculture Development (DAD) and a Directorate of Aquaculture Research (DAR). The DAD was responsible for harmonizing legal, regulatory and institutional frameworks; extension services; and access to quality inputs and to markets, while DAR oversaw demand-driven research, initiating and maintaining collaboration and partnerships and improving access to inputs (fingerlings and feed) (MOFD 2010).

The key institutes in the development of aquaculture in Kenya are:

- DATD, which facilitates extension for the sector, with a main objective of promoting and facilitating development of sustainable commercial aquaculture
- The Kenya Marine and Fisheries Research Institute (KMFRI), which is a state-owned corporation established by an act of parliament. KMFRI is mandated to carry out research in which aquaculture is a key component
- The National Aquaculture Research Development and Training Centre (NARDTC), which is responsible for training and extension, regulation of standards in feed and fingerlings and aquaculture curriculum development.
- Other government training and research facilities in the SDFBE (these are listed in Annex 4).

Lack of funding and lack of capacity have been found to compromise the implementation of policies within the intended time frame, making them irrelevant. The lack of funding causes GoK to rely on donor funding for support in developing policy and strategic development programmes, as can be seen in the development of the NAP-2011 and NASDP 2010–2015, which the GoK developed with support from FAO (MOFD 2010). The reliance on donor funding also makes aquaculture policies and regulations more fragmented. Stakeholder participation in the process of policy development depends far too much on external funding (Ngugi & Manyala 2009). Implementation of key activities in the development of aquaculture, such as extension services and training, is low and slow due to lack of staff and funding. Aquaculture extension implementation is therefore weak compared to other agro-based sectors, despite them all falling under the same ministry. Despite having basic policy guidelines and regulations, the full potential of aquaculture cannot be harnessed at present, which means the issues that the NAP-2011 and NASDP 2010–2015 were supposed to solve still persist. For instance, the two documents explicitly target the challenges of quality and quantity of fingerling and feed, access to markets and value addition, access to credit facilities, increased private sector involvement and increased technology and knowledge (MOFD 2008, 2010); however, these issues still limit aquaculture sector growth (Shitote et al. 2013, Munguti et al. 2014a).

5.1.3 Lack of reliability

The stagnation of aquaculture is closely related to unreliable policies and regulations. The present policy direction in the aquaculture sector hinges on various national policies for food production, economic prosperity, industrialization, poverty reduction, environmental conservation, and sustainability. It is focused on promoting sustainable and efficient aquaculture, strengthening the institutional framework, sustained funding, capacity-building, commercialization of aquaculture, quality assurance in products and inputs, infrastructure development, aquaculture research, and promoting regional and international cooperation (Ngugi et al. 2009). However, most policy documents have not been effective in developing the aquaculture sector. The slow and uncoordinated growth of aquaculture can also be related to the general lack of a comprehensive policy and legal frameworks since the independence of Kenya. A coherent and reliable set of regulations for aquaculture is still lacking. The present legal and regulatory framework for aquaculture policy may be characterized as fragmented and weak. Furthermore, there has been a lack of aquaculture-specific regulatory frameworks with regulations. An example is the Fisheries Act, CAP 378 from 1991, in which aquaculture is only briefly mentioned (MOALF 2010).

One challenge in managing aquaculture is that the sector has been managed by 12 ministries since independence in 1963. The migration of the sector from one ministry to another has inhibited development of the sector, since each ministry has prioritized aquaculture development differently (MOFD 2008). Hosting aquaculture in different ministries in which there is little understanding of what aquaculture entails has delayed the development of relevant policies and regulations and consequently resulted in a failure to create a conducive environment for stakeholders in the sector. For instance, the sector has previously been guided or managed under tourism, wildlife, environment or natural resources, whose development agendas may not be appropriate for aquaculture (Ngugi & Manyala 2009). While there are some (minimal) regulations, there is a lack of reliable mechanisms and institutional capacity to reinforce them. This leads to unregulated practices in the industry that can give rise to serious quality issues in feed and fingerling production. Institutional governance within the supply chain therefore lacks reliability, and this weak policy and regulatory framework compromises interactions in the supply chain.

A critical look at FFEPP shows a lack of long-term commitment by Kenyan authorities. The FFEPP initially was a success, based on the impressive growth rates in the first years of the programme. However, the subsidies driving that growth were suddenly removed, rather than gradually reduced as the industry began to make profit. The sector experienced a shock, and farmers found they could rely far less on the initiatives of the GoK. Many of the pioneer farmers abandoned fish farming (Rurangwa et al. 2015) due to this lack of reliability of institutional governance.

5.1.4 Lack of consistency

Various sections of legislation overlap, bringing about contradictions and conflicts and compromising the reliability of aquaculture policies and strategies. For example, a farmer interested in culturing and exporting aquarium fish needs to seek permits from different departments outside the Fisheries Department. While the permit and licence for aquarium fish movement is under the current Fisheries Act, the certification for export is with the Veterinary Department (Ngugi & Manyala 2009). In addition, the Public Health Act and the EMCA are in conflict with regards to utilization of wetlands and water pools: NAP-2011 and NASDP (2010–2015) describe wetlands as areas for aquaculture potential, and actually recommend the exploitation of natural resources such as lakes, rivers and wetlands for aquaculture. However, the Public Health Act considers wetlands a health nuisance and as hazards that should be drained and disinfected. EMCA prohibits the use, drainage or utilization of wetlands for either personal or commercial use without prior written permission from the authority and after carrying out an environmental impact assessment (GoK 1999, Ngugi & Manyala 2009). This may prove restrictive for small-scale farmers, who may find it an added cost to carry out environmental impact assessments. Furthermore, while farmers would want to carry out fish farming in the vicinity of irrigation schemes, they may find themselves in conflict with Sections 26 (a) and (b) of the Irrigation Act (2012), especially during times of water scarcity (GoK 2012). Furthermore, the Draft Wetland Policy acknowledges that fish farming within wetland areas is increasingly becoming an alternative to natural production and that wetlands are important nursery grounds for replenishing natural fish stocks. However, it does not recommend measures to compromise between fish production in wetlands and conservation (GoK 1999). Furthermore, the Draft Wetland Policy prohibits the introduction of alien species such as *Salvinia* sp. into wetlands (NEMA 2008). Yet some farmers are actually growing aquatic weeds like *Salvinia* sp. as potential ingredients for fish feed, unaware of the dangers posed by the weed to the aquatic environments (outcome of the workshop discussion). This shows that despite the presence of legislation, aquaculture practitioners are not aware of such risks. Furthermore, stringent adherence to some regulations by small-scale farmers may not be possible, particularly not in the case of conflicting policies, strategies and acts. It is also important to note that lack of synchrony in implementing programmes that cut across ministries has negatively affected aquaculture development. For example, a strategy for development of infrastructure relevant to aquaculture will face challenges when the actual implementation for building roads, electricity and training facilities falls under other ministries (Ngugi & Manyala 2009).

Integration of different GoK stakeholders to implement aquaculture policies is difficult due to their conflicting development agendas or to poor coordination. For instance, the implementation matrix for policies integrates various GoK ministries and agencies, as well as the public and private sectors and even links national aquaculture programmes and projects to international programmes and projects (MOFD 2008, 2010). An example is the NAP-2011 implementation matrix, which incorporates KMFRI, the Kenya Plant Health Inspectorate Service, Kenya Oceans & Fisheries Service, KEBS and training institutes as collaborators in the implementation of the aquaculture development policy guidelines. These organizations are responsible for quality assurance, research, training and curriculum development. However, a coordinating mechanism is lacking that would facilitate all GoK departments to implement aquaculture policies and legislation.

5.1.5 International compliance

Efforts by the GoK to align national regulations with international regulations are an essential step forward. However, this is still a work in progress. The test is if these efforts eventually result in implementation and enforcement. As such, the regulations are not reliable yet, simply because they are not effective yet. The aquaculture sector does currently benefit from international and regional regulations that were mainly developed for capture fisheries. For example, until the 2000s, fish and fisheries products could not enter the EU market due to food safety issues. To deal with this the GoK developed and published the Fish Quality Assurance Regulations in 2000. These regulations created a competent authority with powers to monitor and regulate all fish handling and processing – including fish from aquaculture harvests. This demanded that the food safety standards of the EU were to be met, and so greatly reduced the executive EU bans that had plagued Kenyan fish exports to the EU markets. To enable exports, the GoK also established the Export Processing Zone Authority (EPZA) in 1990 by the Export Processing Zone Act CAP 517 to facilitate export-oriented investments and develop an enabling environment for similar investments (Rothuis et al. 2011).

5.2 Reliability of economic transfers

This section focuses on the degree to which the reliability of economic transfers provides an enabling environment for private investment and enhances trade opportunities.

The following opportunities and constraints affect the reliability of economic transfers:
- Lack of access to credit
- Subsidies
- Taxation and waivers.

These opportunities and constraints are briefly discussed below.

5.2.1 Lack of access to credit

A number of financial institutes finance agricultural enterprises. The GoK has actually been encouraging farmers to seek credit from the Agricultural Finance Corporation (AFC), which has traditionally served the maize and livestock sectors. However, due to the lack of a clear economic analysis and economic understanding of the aquaculture sector, it has been a challenge for farmers to benefit from credits from these financial institutes. Also, development-oriented institutes such as FAO, UNDP and the Belgian Survival Fund have had challenging experiences in the western part of Kenya, where farmers were unable to repay loans (Ngugi & Manyala 2009). If businesses do not have a clear return on investment, financial institutes will not consider them reliable.

5.2.2 Subsidies

Since its introduction, aquaculture has been supported immensely by various national and international organizations. In fact, the failure to wean farmers off subsidies and encourage them to become self-reliant has created a dependence syndrome in aquaculture. For a long time, the support from the GoK to the sector has remained at the "promotion" stage (interview with Mr. Ochieng). Perhaps the most prominent subsidy support that the GoK gave to the sector was through the FFEPP. After a few years, subsidies were suddenly reduced, resulting in demotivated farmers (for more info on FFEPP, see also section 5.1.3).

5.2.3 Taxation and waivers

Since the 1990s when the economy was liberalized, the GoK has maintained a favourable tariff structure to encourage importation of feed ingredients. This has been at 10% for seed cake and 20% for fish meal and cereal bran, and premixes are not subject to any tariff. Manufacturers import ingredients, since it is presumed that they are of better quality. Except for a short period in 2013 when a 16% value added tax (VAT) was introduced on feed (this was later reversed by parliament), the GoK has maintained a zero-rated VAT regime for animal feed. In addition to supporting and encouraging animal feed production, the GoK has had to introduce tax exemptions on imported raw materials for feed manufacture in the financial year 2016/2017 (GoK 2016). These measures are hoped to be a step towards increasing availability of commercial feeds.

5.3 Reliability of soft instruments

This section focuses on the degree to which the reliability of soft instruments provides an enabling environment for private investment and enhances trade opportunities. The following opportunities and constraints affect the reliability of soft instruments:
- Public–private partnerships
- Innovation platforms
- Programmes and projects.

These opportunities and constraints are briefly discussed below.

5.3.1 Public–private partnerships

The GoK advocates for private–public partnerships (PPPs) in a strategy where individuals or groups of individuals with interest in a sector can invest in public development under an agreement with the GoK, then recover their investment. This approach has been expressed in major policy documents, including the Strategy for Revitalising Agriculture (SRA).

The GoK envisions that PPPs can work best in providing basic infrastructure for aquaculture development, creating a legal framework and policies for aquaculture development, encouraging research in aquaculture as well as developing a monitoring and evaluation system, providing land for aquaculture, framing and implementing policies for commercialization of activities in the fisheries sector, involving communities and other stakeholders in the process of policy formulation and implementation, encouraging the private sector to drive the growth of the aquaculture sector, and in service provision through dialogue and joint programmes. These measures are still at the developmental stages, and the final approach could change in time (Ngugi & Manyala 2009).

PPPs have been successful in fingerling production, feed processing and marketing. For instance, standards for the production of feed and fingerlings to be used by entrepreneurs were developed through a collaboration between the GoK (KEMFRI, KEBs), farmers and feed manufacturers. Thereafter, the GoK accredited them (Munguti et al. 2016). The ministry then bought fingerlings and feed from these accredited entrepreneurs for the FFEPP and distributed them to farmers. The GoK also procured fish feed pelletizing machines and distributed them in 54 constituencies (see photos in Annex 6).

A PPP option in extension has not been explored, though it is a critical area that aquaculture can benefit from. Given the many GoK aquaculture facilities (specifically those targeting fingerling production and extension) distributed around the country that are without equipment and facilities, it has been recommended that private entrepreneurs could equip them and run them with the GoK having an oversight authority (Ngugi & Manyala 2009).

A last example from the international domain is FoodTechAfrica. This is a public–private initiative combining the strengths of Dutch agrifood companies (mainly small to medium-sized enterprises), knowledge institutes, government agencies and their East African counterparts to improve food security in East Africa through the establishment of a fully integrated aquaculture supply chain (Larive 2015).

5.3.2 Innovation platforms

The Aquacultural Association of Kenya (AAK) is a lobby group, but it also acts as a platform that links farmers to training initiatives. Using its strengths as an umbrella body for all fish farmers in Kenya, it has partnered with other sector-relevant institutes and organizations to train farmers on aquaculture best practice. It has also provided a platform to give farmers and other stakeholders information about networking and communication. The association has also helped farmers carry out collective marketing of products and linked farmers to international markets and service providers. By partnering with the Kenya Agriculture Productivity and Agribusiness Project, AAK enables farmers to access a market for their produce by using vendors to form aquaculture product outlets, increase their earnings through diversifying aquaculture products and synchronize production to have sustainable fish production from clusters. Traders benefit from marketing and production information, and consumers benefit from product information while also getting quality products.

AAK has also provided a platform for the United Nations Industrial Development Organization (UNIDO) to implement the Standard and Market Access Programme (SMAP), which promotes competitiveness and market access for the animal- and plant-based products made in Kenya for local and international markets. To implement the SMAP, UNIDO partnered with KEBS, Department of Veterinary Services and Kenya Plant Health Inspectorate Service to train Trainers of Trainers from different parts of the country about sanitary requirements and residue monitoring plans for aquaculture in Kenya. The trainees were therefore able to ensure the compliance of fish farmers to the set standards for farmed fish for the EU market.

AAK also provides links to other affiliate associations and organizations, such as Commercial Aquaculture Society of Kenya, Kenya Fish Processors and Exporters Association and the International Association of Fish Inspectors.

5.3.3 Programmes and projects

A final example of a new initiative is the Kenya Market-led Aquaculture Programme (KMAP), led by Farm Africa. KMAP seeks to empower farmers to be more profitable, increase income and improve family nutrition. This programme will be implemented with partners that include PUM from the Netherlands, Wageningen University & Research, Lattice Consulting Ltd, BoP Innovation Center and WorldFish. The programme's timeline is 2016–2019, and it is limited to the western parts of the country. KMAP also proposes to set up a platform with biannual meetings to discuss the needs of stakeholders, share findings of KMAP studies and exchange information on changes in policies and regulations. A wide variety of stakeholders will be involved, such as the private sector (feed and fingerlings producers, grow-out producers), government organizations (GoK departments, EKN), NGOs and other donors (Farm Africa 2015).

Since 2011, Farm Africa has helped to promote fish production in western Kenya under the aqua shops project, signalling a weakness in aquaculture extension. The overall aim of the aqua shops project is to establish a commercially viable input and service distribution system in selected counties in western Kenya. The aqua shops are based on a franchise model and are managed by local business owners who establish shops and provide smallholders with inputs and technical advice on best aquaculture practice. Through this approach, farmers are provided with market information and are taught how to link their businesses with markets to generate additional income (Farm Africa 2016). Through the project there has been an increase in connection between farmers and entrepreneurs, in production and in farmer incomes. Based on the lessons learned, Farm Africa envisions forming partnerships with financial institutes such as Equity Bank and Kenya Women Microfinance Bank, clustering of farmers and attracting private investment in feed manufacturing (Farm Africa 2016).

Farm Africa is running the aqua shops project in five western counties of Kenya – Busia, Kakamega, Kisumu, Vihiga and Kisii – to support fish farmers in terms of equipment, feed and technical knowledge needed for their ponds to thrive in the long term. Aqua shops are an invaluable source of quality support and training for fish farmers in Kenya. The aqua shops project aims to enhance the entrepreneurial skills of fish farmers by:

- Providing farmers with training on marketing and selling their produce, using online platforms
- Providing farmers with fish feed and fertilizers, as well as with technical aquaculture advice so they can set up and manage their own ponds
- Piloting profitable new schemes, such as intensive fingerlings production
- Using gained knowledge to develop a franchising model, which, if it works, can be used throughout Kenya and across East Africa.

The project has grown significantly since it was set up in 2011, with 56 shops set up in five years, benefiting over 7,500 farmers and increasing their incomes by 63%. Sales of fish have increased through a partnership with digital platform E-soko, which connects farmers with traders online and is also used to send technical tips to farmers via text message.

Table 2 *SWOT reliability of institutional governance*

Institutional context	Strengths	Weaknesses	Opportunities	Threats
Regulations	GoK intervention on quality of fingerlings and feed; aquaculture policy and NASDP 2010–2015; tax exemptions; creation of EPZA; development and implementation of Fisheries (Fish Quality Assurance) regulations 2000	Uncoordinated development approaches by different sector players (national/county GoK, NGOs, donors); lack of coherent GoK policies; lack of implementation and enforcement on fingerlings and feed quality; low priority of fish farming to policymakers; slow implementation of NAP-2011 and NASDP 2010–2015; lack of supportive infrastructure	Specific policies tailored to cater for local sector needs; creation of environment to help private sector to invest in strategic areas; availability of support from bilateral and multilateral organizations for implementation of policies; review of NAP-2011 and NASDP 2010–2015; establishment of innovation platform to stimulate stakeholder cooperation	Decentralization weakens implementation of policies; poor quality raw materials, feed, fingerlings; current policy does not strongly support small-scale farmers Expiry of NASDP 2011–2015; low funding to implement policies
Economic transfers	GoK subsidy through FFEPP; development of processing facilities; provision of feed processing machinery; training on production and provision of loans from banks, microfinance institutes and NGOs to cooperatives; insurance by financial institutes; AFC; tax waivers on raw material for feed	Drastic reduction of GoK support; failure of farmers to manage after GoK reduced support through FFEPP; lack of credit from financial institutes; small-scale farmers do not have bank accounts and do not repay loans; financial institutes do not offer credit; lack of economic analysis and economic understanding of aquaculture sector; lack of business plans by small-scale farmers; FFEPP; in the past most support focused on promoting rather than commercialization of aquaculture	Growing international PPPs; commercialization of aquaculture will open opportunities for credit	Farmers failing to pay back loans; stagnation at small-scale levels of farming; unsustained development programmes; dependency syndrome
Soft instruments	County GoK prioritizing aquaculture on the ASDSP programme; GoK support for PPPs; availability of GoK infrastructure to host PPPs; AAK creating platforms for innovation; vibrant AAK; success of Farm Africa's aqua shops	PPP still at developmental stages; weak institutional framework to guide PPPs; lack of PPP in extension	International PPPs; PPPs in extension	Stagnation of sector

5.4 Recommendations

This chapter aimed to provide insight into the strengths, weaknesses, opportunities and threats in terms of the reliability of institutional governance of aquaculture in Kenya. The recommendations for more reliability of institutional governance are to:

- Update the NAP and NASDP to make them more specific and make the objectives more realistic
- Provide strategic guidance to the sector in the long term and plan for the right investment, taking guidelines to address environmental and social impacts such as provided by FAO for responsible aquaculture development, zoning and area management into consideration
- Use soft instruments such as PPPs and innovation platforms as an opportunity to increase the reliability of institutional governance in the near future and to support mutual cooperation to tackle the issues of feed, fingerlings and knowledge.
- Informed decision-making on programmes, projects and investments can only occur with consistent and reliable facts and figures. There is urgent need to support the supply chain stakeholders, GoK entities and donors with such data. Improve the capacity-building for the Kenya National Bureau of Statistics so it can professionally collect sound data on aquaculture performance

6 Resilience of innovation support systems

This chapter aims to describe the key knowledge and innovation support system components, including research, extension, training and business development services engaged in the aquaculture sector, and their resilience. Resilience refers to dynamic adaptive capacities that enable stakeholders and systems to adequately respond to changing circumstances. It is increasingly recognized that agricultural innovation does not happen in isolation. Rather, innovation is the outcome of collaborative networks where information is exchanged and learning processes happen (Knickel et al. 2009).

In this section, we analyse how the innovation support system interacts with the supply chain and policy and regulatory stakeholders to support dynamic and continuous technical, institutional and social innovation in the sector. The analysis looks at the capabilities of innovation support components and how different types of support structures contribute to supporting such innovation. Finally, the physical and virtual infrastructure support required for innovation to happen will be analysed in terms of presence and quality.

The focus in this chapter is on stakeholders (government agencies, NGOs, research institutes and industries), institutes, interactions and infrastructure, following the approach of Wieczorek and Hekkert (2012).

6.1 Stakeholder interactions and institutions

This section focuses on the capabilities of innovation support components and their interactions. The following topics will be discussed:

- Innovation support system components
- Interactions between the supply chain and government agencies.

6.1.1 Innovation support system stakeholders

The involved stakeholders include government agencies, NGOs, research institutes and industries. The GoK, NGOs and foreign governments support research and dissemination of research findings through extension. There have been a lot of interventions from different organizations, yet funding for the sector is still meagre. Although many organizations have participated in research, training and extension in aquaculture, it has been uncoordinated; many farmers complain they are confused by different extension support by different organizations. There are also reports that some training is not relevant for the trainees. The GoK plays a significant role in providing extension, and it is supported by universities and programmes funded by NGOs. Still, it does not seem that aquaculture has a very high priority at different GoK departments. Although the universities carry out extension, it is not a major component of their mandate and is not sufficient. This is partly an issue of lack of staff with sufficient capacity. Although the NARDTC has a mandate to review and develop aquaculture training programmes, universities have their own curriculum development procedures, which are defined by the Commission of University Education. The Commission may only invite the NARDTC at the stakeholder level as a participant. The training programmes then produce graduates who are not ready to work and who have to undertake additional training specifically related to the feed industry (interview with Mr. Kitesh).

6.1.2 Interactions between the supply chain and government agencies

In the aquaculture sector, collaborative networks between institutes, organizations and platforms for research, extension training and business development services are weak, which compromises the resilience of the innovation support systems. These collaborative networks would be more effective if the proposed Aquaculture Advisory and Research Board were in place. The proposed board is represented by development partners, the public sector (Directorate of Aquaculture Research and Technology, KMFRI and NEMA), the private sector (including representation from associations, input suppliers, credit institutes and civil societies) and would have provided oversight mechanisms in the implementation of NASDP, where research, extension, training and business development services are envisioned (MOFD 2010). Because stakeholders in the sector have been working in isolation, their results have not been effective for farmers. For instance, universities and KMFRI both have a research mandate, but have carried out their research in isolation from the Directorate of Aquaculture, which was the department carrying out aquaculture extension services. Currently – to ensure sustainability of programmes initiated by donor-funded projects – different aquaculture departments are involved so that the research and policy as well as the extension component are involved. This is unlike in the past, when different projects and programmes worked in isolation with a single GoK department or with none at all (Ngugi & Manyala 2009).

6.2 Physical and virtual infrastructure

This section focuses on the presence and quality of physical and virtual infrastructure and how it supports innovation. The following topics will be discussed:

- Aquaculture extension services
- Training
- Research.

6.2.1 Aquaculture extension services

The GoK is the key driver of extension and farmer training in aquaculture. However, implementation of aquaculture development activities, including extension, is practically impossible given the scarcity of staff available (Ngugi & Manyala 2009). Extension services in aquaculture are mainly offered by the Department of Fisheries, which is currently under the SDFBE. Other stakeholders – including NGOs, AAK network platform, GoK agencies and institutes such as universities, research stations and programmes under bilateral and multilateral funding – are involved in research, but this is uncoordinated. Furthermore, extension programmes carried out by players other than the GoK are not always sustained, since they can only work within certain timelines and funds. Once these are exhausted, the role of extension remains the sole responsibility of the GoK. In the past, research, training and extension of aquaculture have been conducted separately by different stakeholders, which created some disharmony in implementation and some confusion for farmers (Ngugi & Manyala 2009). Therefore, the GoK has begun to harmonize all these activities for the benefit of farmers.

Extension in aquaculture is not part of a stakeholder platform such as NALEP, which has been successful in livestock and other agro-based sectors. The concept of NALEP was as an evolving agricultural development and poverty alleviation programme that used the experiences learned from a successful programme supported by Swedish International Development Cooperation Agency (SIDA) called National Soil and Water Conservation Program (NSWCP) (1974–2000) that reached up to 1.5 million farmers (Cuellar et al. 2006). The programme combined monitoring and evaluation, training, collaboration and research, as well as a focus on gender and poverty in its implementation, ensuring that extension networks were strong and functional (Cuellar et al. 2006). Considering the success of NALEP, it is clear that aquaculture has been disadvantaged by not being part of this extension programme.

The weakness in aquaculture extension and training for farmers also lies in its structure: GoK ministries implement extension based on administrative boundaries where there are discrepancies in the number of personnel for different locations. While some locations will have a cascading administrative organization from a large administrative location to a small administrative location, some areas will have only one person staffing a very large administrative region, such as a district that might be in excess of 400 km^2. To bridge this gap, other institutes and agencies have supported extension, including the Lake Basin Development Authority, universities such as Egerton University and Moi University, and KMFRI (Ngugi & Manyala 2009). Some NGOs and bilateral organizations have also engaged in extension and farmer-training work, which started with fisheries officers and university students then cascaded down to fish farmers. For instance, the Pond Dynamics / Aquaculture Collaborative Research Support Program (PD/A CRSP) from Oregon University, sponsored by USAID, increased pond management skills of fisheries personnel involved in aquaculture extension in Kenya and also trained university students likely to graduate and work as extension officers in the aquaculture subsector. At the request of farmers, the programme also delivered farmer education days. Farm trials were conducted in conjunction with the extension officers, and farmer field days – which could accommodate more farmers – were organized to supplement the on-farm trials (Veverica et al. 2001). These programmes can only be successful if they partner with existing GoK facilities, such as the NARDTC. They are limited in terms of coverage and time and may have a narrow focus, such as on a region of high potential, to maximize their limited resources. The GoK acknowledges that extension services are inadequate; during the FFEPP a number of new extension officers were employed to boost extension services (MOAFD 2013a).

6.2.2 Training

There are two types of training. The first type is training of farmers, which is part of extension, and is done through the NARDTC and its sister centres spread across the country (see Annex 4). The second type is educating graduates who will work in aquaculture as extension officers, researchers or in Training of Trainers. This education has been carried out by universities and diploma colleges. Training and extension have focused on production: pond management, culture systems, breeding, feed formulation and farm management. However, the full utilization of this training is still low for a number of reasons, including land policies, poor quality inputs and financial constraints (Ngugi & Manyala 2009, Shitote et al. 2013). Training and extension to farmers is delivered by Farmer Field Schools, at on-farm trials and through one-on-one individual farmer interaction with members of staff at the demonstration centres that are distributed in all aquaculture potential areas (Ngugi & Manyala 2009, Munguti 2014). The NARDTC has been pivotal in this regard. Apart from providing on-site extension and training to farmers, the NARDTC is also equipped with facilities (hatcheries, laboratories, different types of ponds for research and culture) that can host students either for industrial attachment (internship) or for MSc or PhD research. In addition, the centre has hosted large projects such as BOMOSA and PD/A CRSP whose findings are packaged as extension products for farmers. Since the centre carries out production and research on warm-water fish, its activities target farmers in this sector, looking specifically at issues such as production, stocking density, breeding and feed formulation. NARDTC currently focuses on developing the entire aquaculture supply chain in collaboration with the private sector and is also key in helping county governments to realize faster sustainable growth in commercial aquaculture. NARDTC has an immense mandate of training certification and accreditation of county trainers, review and development of aquaculture training curriculum, maintenance of a National Aquaculture Database as well as being in charge of standards for inputs. However, its involvement in the development of curricula in the universities is limited to the stakeholder participation stage.

There are several examples of BSc courses in Kenya that also deal with aquaculture. The University of Eldoret (previously a campus of Moi University) offers a Bachelor of Science course titled 'Fisheries and Aquatic Science'. At other universities, aquaculture at BSc levels is sometimes integrated in studies such as animal sciences, applied aquatic sciences, aquatic resource conservation and development, marine and fisheries studies and zoology.

6.2.3 Research

Initially, training and research in aquaculture were mainly shared among three main organizational bodies: the Department of Fisheries, KMFRI and Moi University (Ngugi & Manyala 2009). This has proved challenging, given their varying policies and overlapping mandates. There is currently an extensive government infrastructure in support of aquaculture research, which includes GoK fish farms that are available for research purposes, fingerling supply and training (Rothuis et al. 2011). Universities are also equipped with infrastructure for research:

- Egerton University has research ponds, hatchery facilities and a water quality research laboratory. The University is also home of an Agro-Science Park that provides an incubation space and infrastructure for agro-based innovations, which are later turned into products and services for

commercialization. The park is also a platform for collaboration and partnerships with local and international organizations and institutes such as the Kenya Agricultural & Livestock Research Organization, NEMA, KEBS, the World Agroforestry Centre, the Kenya Industrial Research & Development Institute and the International Livestock Research Institute. Within the park, the university has an Aquaculture Centre purpose-built for training students and farmers as well as for research and production of fingerlings.
- Eldoret University also has research ponds and hatchery facilities, as well as a fish feed nutrition laboratory.

Funding from the GoK for aquaculture research is minimal; therefore, most research is funded through collaborations and partnerships between the GoK and programmes and projects that have been funded through, for example, FAO, EU or USAID. Some of the notable research projects that have had an impact on aquaculture include the Lake Victoria Environment Management Programme; and BOMOSA, which is a collaboration between, among others, BOKU University in Austria, Moi University and the NARDTC (Ngugi & Manyala 2009). Much of this research has focused on species biology, feed quality and quantity, breeding, culture environment and production systems. Little attention has been given to the functioning of fish markets and socioeconomic aspects of the aquaculture sector. In order for research to become more comprehensive, it also needs to be conducted in other disciplines to understand the needs in the supply chain. These needs include marketing of products, sourcing of feed and fingerlings, suitability of locations, and socioeconomic issues such as gender and culture. This will create more interest in fish production and increase investment into the sector.

The need to embrace the concept of using universities and research institutes as incubators for innovations was also mentioned during the stakeholder workshop held 19–20 July, 2016.

Table 3 SWOT innovation support system

Support system	Strengths	Weaknesses	Opportunities	Threats
Stakeholder interactions	Presence of many stakeholders (universities, KMFRI, NARDTC, NGOs)	Aquaculture Association of Kenya (AAK) still weak; stakeholders work in isolation; weak collaborative network; uncoordinated interaction; no innovation platform for interaction to share knowledge and ideas	Opportunities for incubation of innovative ideas	Stakeholders work in isolation from each other
Institutions	Strong support from GoK, NGOs and foreign governments to support research, and training and extension; GoK and NGO funding; collaboration (e.g. between GoK and multilateral donors through ASDSP)	Meagre funding for aquaculture; uncoordinated research training and extension from different stakeholders; irrelevant training; uncoordinated promotion of aquaculture due to too many institutes; poor staffing for extension	Opportunity for incubation initiatives at science parks	Farmers confused by the many different stakeholders that do not coordinate their actions
Infrastructure	Designated aquaculture research and training centres through the country; universities equipped with research and training facilities	Dilapidated GoK facilities; low use of GoK facilities by private sector	Use of PPP in extension e.g. use of progressive farmer facilities for training and extension to farmers/research and attachment/internship for students	Structured clear-cut market is lacking

6.3 Recommendations

This chapter aimed to describe the key knowledge and innovation support system stakeholders, including research, extension, training and business development services engaged in the aquaculture sector. The recommendations for more resilient innovation support systems are to:

- Review training and extension programs for farmers, and improve capacity-building of extension officers
- Increase coordination among innovation system supporters by installing the proposed Aquaculture Advisory and Research Board or another multi-stakeholder innovation platform with similar function, and via (digital) innovation platforms to steer knowledge creation to solve problems with feed, fingerlings and other issues in the aquaculture chain.

7 Conclusions and recommendations

The aim of the quick scan is to identify how the aquaculture sector in Kenya performs in terms of the robustness of the supply chain, the reliability of the institutional governance and the resilience of the innovation system. Three research questions were elaborated in the quick scan:

1. What is the robustness of the supply chain?
2. What is the reliability of institutional governance?
3. What is the resilience of the innovation system?

1. What is the robustness of the supply chain?

On the issue of robustness of the supply chain, we conclude that while most of the important elements of the aquaculture supply chain are in place, there is a clear lack of robustness on the input side. To attract profitable business and investment on the input side, the sector needs to reach a certain size and scale. At present, this is not the case.

The economic sustainability of the supply chain is characterized by the following issues:

- The lack of robustness on the input side relates to a lack of access to reliable, affordable and high quality feed and fingerlings (Rothuis et al. 2011, Rurangwa et al. 2015).
- Although there has been growth in number of entrepreneurs, the number of active farmers is still too few and the size of most enterprises is still small. This is limiting the ability of the sector to scale up to a point where the supply chain is robust. There is high demand for fish and a dwindling supply from the capture fisheries. The supply chain is focused on two species, Nile tilapia and the African catfish, which are acceptable to consumers and are easy to culture.
- The number of entrepreneurs in the production side of the supply chain has increased, as has production, with 7,800 entrepreneurs in 2007 and an estimated 20,000 in 2011 (Rothuis et al. 2011). However, after 2011 the number of active farmers decreased due to issues such as reduction of subsidised inputs. Also, entrepreneurial and management skills and technical knowledge are lacking; these are needed to sustain aquaculture in the long term, and their lack is another factor limiting the ability of the sector to grow a robust supply chain.

The environmental sustainability of the supply chain is characterized by the following issues:

- The country is endowed with vast areas of aquaculture potential. The present low level of production makes the aquaculture supply chain environmentally sustainable. However, since production involves the use of water, there is a risk of environmental impacts on aquatic ecosystems once production increases and is not well managed and planned.
- If the sector grows, the demand for high quality local feed will increase. This will increase the demand for feed ingredients, which causes pressures on resources such as land, water and on certain fish stocks used for fishmeal production.
- In addition, when growth is not well managed and planned, increased production can also lead to conflicts with other water users.
- The spread of diseases and parasites threatens the environmental sustainability of the supply chain.

The social sustainability of the supply chain is characterized by the following issues:

- A growing sector means a growth in demand for (local) feed. Feed production uses ingredients such as Omena and other edible products, causing competition for food, especially for poor households.
- Low literacy levels, the influence of culture and religion and the barriers against participation of women and youth in the aquaculture sector are the critical issues affecting the social sustainability of the aquaculture supply chain. Although culture and traditions have great influence on fish consumption, more youth are now consuming fish. However, the low uptake of aquaculture among women and youth still threatens the social sustainability of aquaculture.

The recommendations for more robustness in the aquaculture supply chain are:

- Identify a working business model for Kenyan aquaculture that will move the sector from its current state to medium- and large-scale commercial farming where all elements of the supply chain are robust.
- Strengthen enforcement of standards to curb poor quality of local feed and fingerlings
- Support and promote cluster farming among farmers, which gives them more bargaining power when they purchase inputs and invest in cold storage, processing and marketing
- Improve the skills and practical knowledge of farmers in aquaculture. This can be done by increasing the funding of training and extension programmes. Special help should be given to women and youth, to form groups so they can take up fish farming. In such groups, the practical knowledge and skills of farming and marketing can be taught.

2. What is the reliability of institutional governance?

On the issue of reliability of institutional governance, we conclude that over the past seven years reasonable progress has been made on developing policy frameworks and necessary governmental bodies to lead the aquaculture sector development. The reliability of institutional governance is characterised by the following issues:

- Based on the problems facing aquaculture and the stagnation of the sector since its introduction, we can note that the institutional governance is not yet reliable. Specifically, the problems of poor quality of fingerlings and feed point to a weak institutional framework and the inability of public and private stakeholders to improve these inputs.
- From an institutional governance perspective, it must be noticed that standards on quality for feed and fingerlings are still not effective, resulting in unreliable quality of inputs. This is despite the fact that KEBS is mandated to ensure quality of inputs in the market.
- Regulations for feed and fingerlings are currently lacking, further constraining the development of standards (Ngugi & Manyala 2009, Rothuis et al. 2011, Munguti et al. 2014).
- The low priority that the sector has received from the GoK has caused lack of aquaculture-specific policies and regulations and little attention in GoK development programmes and strategies; although there are numerous policies guiding aquaculture, they are fragmented and generic, making them weak and difficult to implement.
- Subsidies under the FFEPP boosted the sector between 2009 and 2011. However, large budgets were invested in the wrong areas, that is, areas with unfavourable physical and ecological conditions (too cold during part of the year, too dry, unsuitable soils). This, together with a sudden reduction of subsidies for fingerlings and feed, resulted in the reluctance of smallholder fish farmers to continue with production.
- Conflict of aquaculture policies and regulations with those of other GoK sectors and the frequent transfer of the responsibility for aquaculture development from one government entity to another have also limited the reliability of institutional governance.
- As long as aquaculture remains at a small-scale level, the availability of subsidy and credit systems (economic transfers) will be limited. Financial institutes regard aquaculture as a high-risk venture and hence will not give credit. The PPP and innovation platforms are still at the infancy stage, which means that there is opportunity to grow.

The recommendations for more reliability in institutional governance are to:

- Update the NAP and NASDP to make them more specific and make the objectives more realistic
- Provide strategic guidance to the sector in the long term and plan for the right investment, taking guidelines to address environmental and social impacts such as provided by FAO for responsible aquaculture development, zoning and area management into consideration.
- Use soft instruments such as PPPs and innovation platforms as an opportunity to increase the reliability of institutional governance in the near future.
- Informed decision-making on programmes, projects and investments can only occur with consistent and reliable facts and figures. There is urgent need to support the supply chain stakeholders, GoK entities and donors with consistent and reliable data. Improve the capacity-building for the Kenya National Bureau of Statistics so it can professionally collect sound data on aquaculture performance.

3. What is the resilience of the innovation system?

While there is increasing cooperation between stakeholders in the growing aquaculture supply chain, the resilience of the innovation system is far from optimal due to a lack of coordination of efforts and investments (Rothuis et al. 2011). The resilience of the innovation system is characterised by the following issues:

- Most innovation support comes from various national governments and international organisations and NGOs, whose approaches have not focused on enhancing profitability along the supply chain and have not adequately integrated technical and institutional innovations as the driver for sector development.
- The minimal interaction between stakeholders causes weakness in the innovation support system. While the GoK is investing in research infrastructure expected to guide policy and enhance production, the collaboration between researchers and private sector and producer organizations that is necessary for co-innovation to transform the sectors is limited. Lack of coordination creates confusion on the farmers' part when they receive different extension products from different stakeholders.
- The extension system is further limited by low staffing and low financing. Education does not meet the skilled personnel requirements of the industry, and research is not responsive to the supply chain.
- Additionally, inadequate and inconsistent socioeconomic, environmental and production data about the sector is a challenge. The lack of reliable data results in poor sharing of information (and vice versa), something that is essential for the further growth and transformation of the sector.

The recommendations for more resilience of the innovation support system are to:

- Review training and extension programs for farmers, and improve capacity-building of extension officers.
- Increase coordination among innovation system supporters by installing the proposed Aquaculture Advisory and Research Board or another multi-stakeholder innovation platform with similar function, and via (digital) innovation platforms to steer knowledge creation to solve problems with feed, fingerlings and other issues in the aquaculture chain.

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Annex 1 List of respondents

Name	Organization
Vincent Kinyua	Fish farmer, Subukia in Nakuru County
Raymond Mwangata	Nakuru County Government
Roy Aseka	Department of Fisheries, Kitui
Grace W. Njagi	National Aquaculture Research Development and Training Centre
Phoebe Muna	Farmer and entrepreneur of Naivasha Fish Farm
Henry Koech	Nakuru County Fisheries Extension Officer
William Ochieng	Deputy Fisheries Officer, Nakuru County
Dr Joyce Maina	University of Nairobi
Virginia Thuku	Rock Fish Farm
William Matunga	Rongo Fish Farmers Cooperative Society
Kamau Muchiri	Fisheries Department
Arnoud Meijberg	Farm Africa
James Last	Research Officer KMFRI
Ngondu Fish Farmers Cooperative	Farmers group in Njoro, Nakuru County

Annex 2 Semi-structured questionnaire

Theme	Details	Questions
Introduction	Short "history" or background of the stakeholder in the sector	1.1 What is your position/role in this sector?
		1.2 When did you start working in this sector?
		1.3. What did you do for a living before you started working in this sector?
Robust supply chain	Perception of the robustness of the sector according to the stakeholder in terms of economic, social and environmental sustainability of the supply chain	2.1 What are, in your view, the sector's main strengths in terms of economic, social and environmental sustainability of the supply chain? How did they come about?
		2.2 What are, in your view, the sector's main weaknesses in terms of economic, social and environmental sustainability of the supply chain? How did they come about?
		2.3 What are, in your view, the sector's main opportunities in terms of economic, social and environmental sustainability of the supply chain? How did they come about?
		2.4 What are, in your view, the sector's main threats in terms of economic, social and environmental sustainability of the supply chain? How did they come about?
Reliable institutional governance	Perception of the reliability of the sector in terms of the regulations, incentives and soft instruments that support private investments and opportunities for regional and (inter)national trade	3.1 What are, in your view, the main strengths of the sector in terms of regulations, economic and financial instruments and soft instruments that enhance trade and investment opportunities?
		3.2 What are, in your view, the main weaknesses of the sector in terms of regulations, economic and financial instruments and soft instruments that enhance trade and investment opportunities?
		3.3 What are, in your view, the main opportunities of the sector in terms of regulations, economic and financial instruments and soft instruments that enhance trade and investment opportunities?
		3.4 What are, in your view, the main threats of the sector in terms of regulations, economic and financial instruments and soft instruments that enhance trade and investment opportunities?
Resilient innovation support systems	Perception of the resilience of the supply chain in terms of its innovation support system: how can we evaluate the presence and quality of its stakeholders, institutes, interactions and infrastructure	4.1 What are, in your view, the sector's main strengths of the supply chain in terms of the stakeholders, institutes, interactions and infrastructure that enable innovation?
		4.2 What are, in your view, the sector's main weaknesses of the supply chain in terms of the stakeholders, institutes, interactions and infrastructure that enable innovation?
		4.3 What are, in your view, the sector's main opportunities of the supply chain in terms of the stakeholders, institutes, interactions and infrastructure that enable innovation?
		4.4 What are, in your view, the sector's main threats of the supply chain in terms of the stakeholders, institutes, interactions and infrastructure that enable innovation?
Next steps		5.1 What are, in your view, the major issues that need to be addressed apart from those we have already discussed?
		5.2 What would they require?

Annex 3 List of workshop participants

Name	Organization
Teresia Wakahia	Kenya Women Holding
Vincent Kinyua	Fish farmer, Subukia in Nakuru County
Raymond Mwangata	Nakuru County Government
Roy Aseka	Department of Fisheries, Kitui
Grace W. Njagi	National Aquaculture Research Development and Training Centre
Phoebe Muna	Farmer and entrepreneur of Naivasha Fish Farm
Henry Koech	Nakuru County Fisheries Extension Officer
Dr Joyce Maina	University of Nairobi
Timothy Majani	Wito Fish Farm
Virginia Thuku	Rock Fish Farm
Meshack Kimondo	Jomo Kenyatta University of Agriculture and Technology
Jeremiah Mbugua	Jomo Kenyatta University of Agriculture and Technology
William Matunga	Rongo Fish Farmers Cooperative Society
Kamau Muchiri	Fisheries Department
Arnoud Meijberg	Farm Africa
James Last	Research Officer KMFRI

Annex 4 Education, training and extension

This annex provides a list of institutes of higher education offering training in aquaculture and fisheries studies and Government of Kenya institutions offering extension and training under the State Department of Fisheries and Blue Economy institutes of higher learning.

Eldoret University, formerly the Chepkoelel campus of Moi University: The institute offers a four-year BSc in Fisheries and Aquatic Sciences, with compulsory courses in aquaculture in the third and fourth years of study. It also has a two-year MSc and a PhD in fisheries with an aquaculture option.

Egerton University: offers a BSc in Applied Aquatic Sciences, with a course in aquaculture in the third year and courses in fish diseases and parasites and fish nutrition in the fourth year of study. Egerton also has a two-year MSc and a PhD in limnology. The Department of Animal Sciences offers a BSc in Animal Science, where aquaculture is taught in the third year of study. The Department has also proposed a BSc in aquaculture that is yet to be launched. The Biological Sciences Department also hosts an international MSc in limnology and wetland ecosystems in collaboration with the Austrian Academy of Sciences and UNESCO-IHE.

Nairobi University offers a BSc in aquaculture.

Kenya Wildlife Training Institute offers a two-year course in fisheries. Courses in aquaculture are also offered.

GoK facilities used for extension, farmer training and production of fingerlings and their location in the country:
- National Aquaculture Research Development and Training Centre (NARDTC), Sagana, currently referred to as Sagana National Fish Culture Farm, in Central Kenya
- Kisii fish farm training centre, western Kenya
- Kiganjo trout farm, central region of Kenya
- Ndaragua trout farm, central Kenya
- Chwele fish farm, in western Kenya
- Lake Basin Development Authority, in western Kenya
- Wakhungu fish farm, in western Kenya
- Sangoro Research Station, in western Kenya
- Kabonyo fish farms, in western Kenya
- Kegati Research Station, in western Kenya
- Ngomeni fish farm, in the coastal region.

Annex 5 Input and service providers

- Naivasha Fish Farm: in the Central Rift Valley one hour's drive from Nairobi; produces catfish fingerlings and has stocked tilapia brooders for production of tilapia fingerlings (personal communication and interview with the proprietor, Ms Phoebe)
- Dominion Farms: in the western part of Kenya in Siaya County; produces extruded tilapia feed (author's communication with the manager in charge of fish production during a visit in November 2015, before the present study)
- Mwea Aquafish Farm: in the central part of Kenya in Kirinyaga County; sells tilapia and catfish fingerlings; gives technical services in the form of advice to farmers
- Aqua shops: Farm Africa's aqua shops project – designed to provide a network of outlets in six locations in western Kenya for provision of fish feed, manure, market linkages and technical advice to farmers
- IVONIK (German company): offers consultancy for formulation of feed for poultry, pigs and fish feed based on amino acids (interview with salesperson Mr Malala)
- Sigma Feeds Ltd: manufactures feed for livestock. Launched a fish feed production line in 2016/2017 and is currently producing floating tilapia feed pellets of various sizes (interview with Managing Director Kirtesh Shah; www.sigmafeed.com)
- Jewlet Fish Farm: in Homabay County in the western part of the country; formulates both sinking and floating pellets and produces fingerlings for sale (interview with Manager, J. F. Were)
- Unga Group Limited produces livestock feeds and has plants in Nairobi, Nakuru, Eldoret and Mombasa. With the help of FoodTechAfrica the company brought in Dutch expertise and launched a fish feed line in 2017 with a focus on tilapia feeds.

Annex 6 Photos

Figure A6.1 *Imported fish feed from a Dutch company.*
Some farmers in Naivasha prefer imported feed over the locally manufactured fish feed
Images courtesy B. O. Obwanga

Figure A6.2 *Mwea Aquafish Farm*
Images courtesy B. O. Obwanga

Figure A6.3 *Left) A farmer in Naivasha. At the farm, one of the 54 fish-feed processing machines was installed.*
(Right) A directory by MOALF that lists input and service providers as well as fish farmers under the AAK umbrella
Images courtesy B. O. Obwanga

Figure A6.4 *Meeting of a fish farming cluster at Pentecostal Church of Eastern Africa church Ngondu in Njoro, organized by Nakuru County Fisheries Department extension officers*
Images courtesy B. O. Obwanga

Wageningen University & Research
P.O. Box 29703
2502 LS The Hague
The Netherlands
T +31 (0)70 335 83 30
E communications.ssg@wur.nl
www.wur.eu

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Wageningen University & Research
P.O. Box 29703
2502 LS Den Haag
The Netherlands
E communications.ssg@wur.nl
www.wur.eu

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